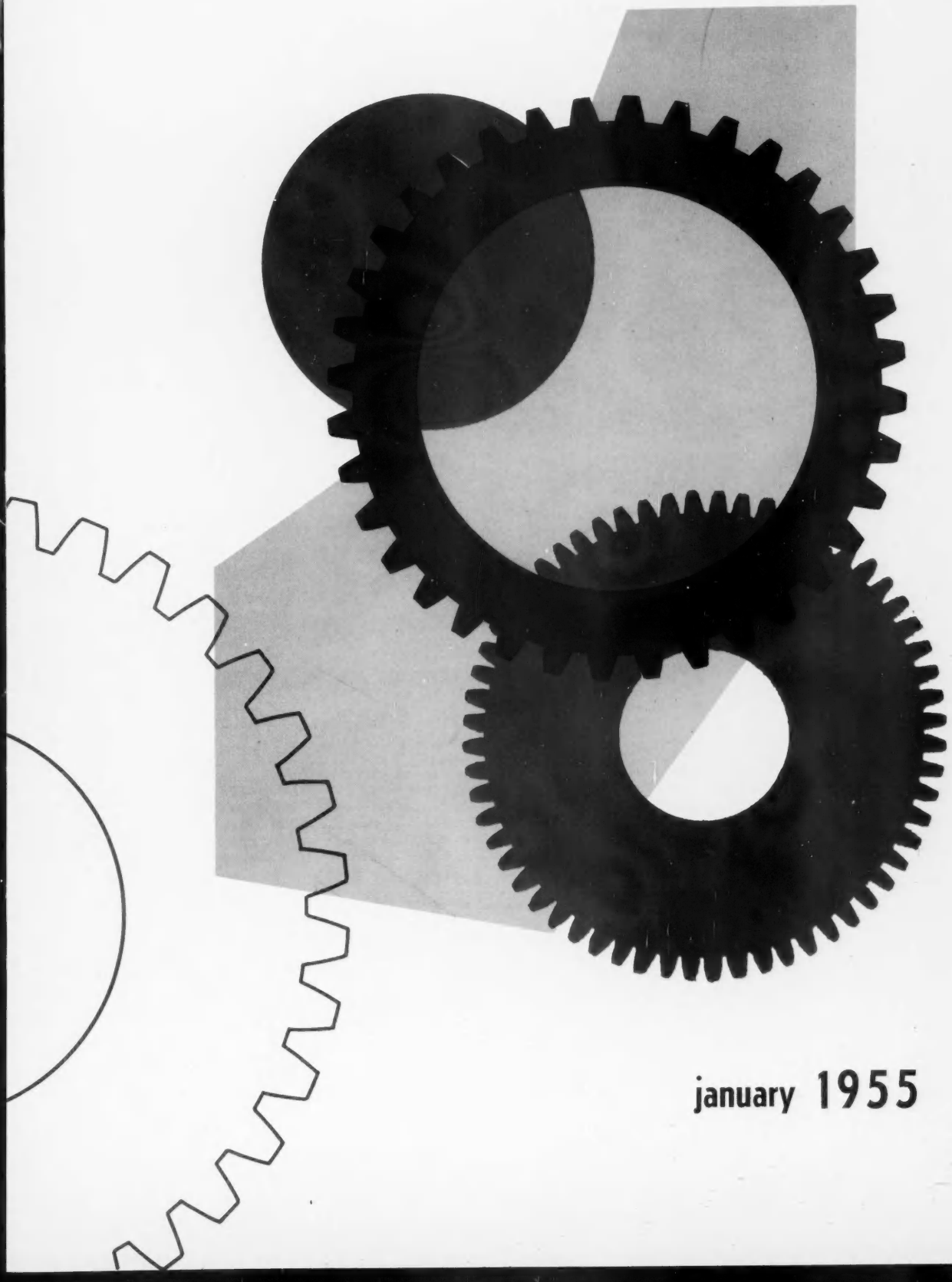
tech engineering news



january 1955

John A. Bauscher, *Class of '43*
speaks from experience when he says . . .

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JOHN BAUSCHER graduated from college in 1943 with a B.S. degree in Metallurgy. After a stint in the Navy, he returned to college as a metallurgical research assistant. In 1949 he received his M.S. in Metallurgy and then came to work at the U.S. Steel Applied Research Laboratory. After just four and a half years, Mr. Bauscher had progressed to Division Chief for Sheet Products Development – responsible for the improvement of present sheet steel products and the development of new and improved types.

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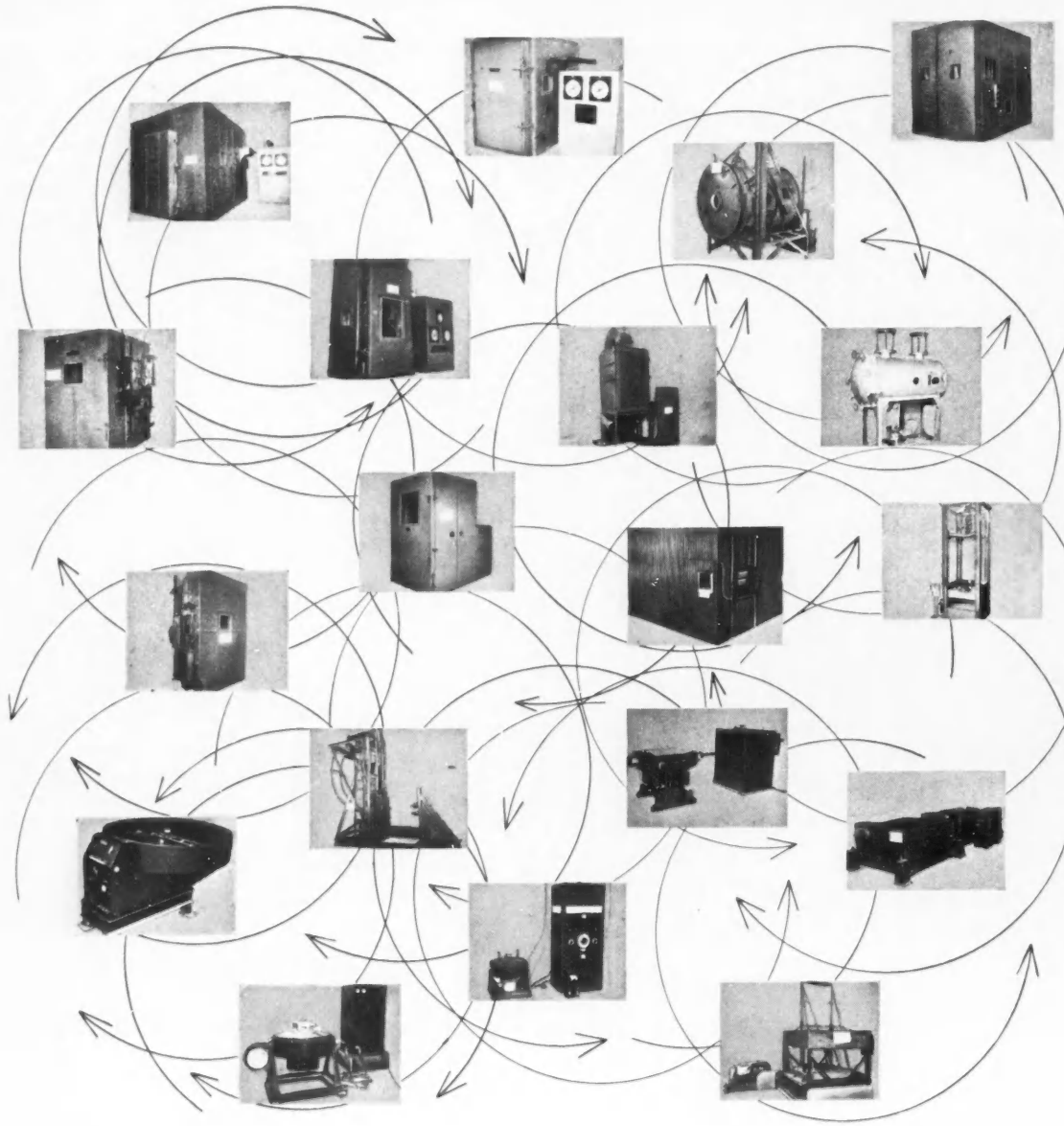

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A MESSAGE TO
COLLEGE ENGINEERING
STUDENTS

from C. H. Weaver, Manager,
Atomic Power Division,
Westinghouse Electric Corporation
University of Pennsylvania, 1936

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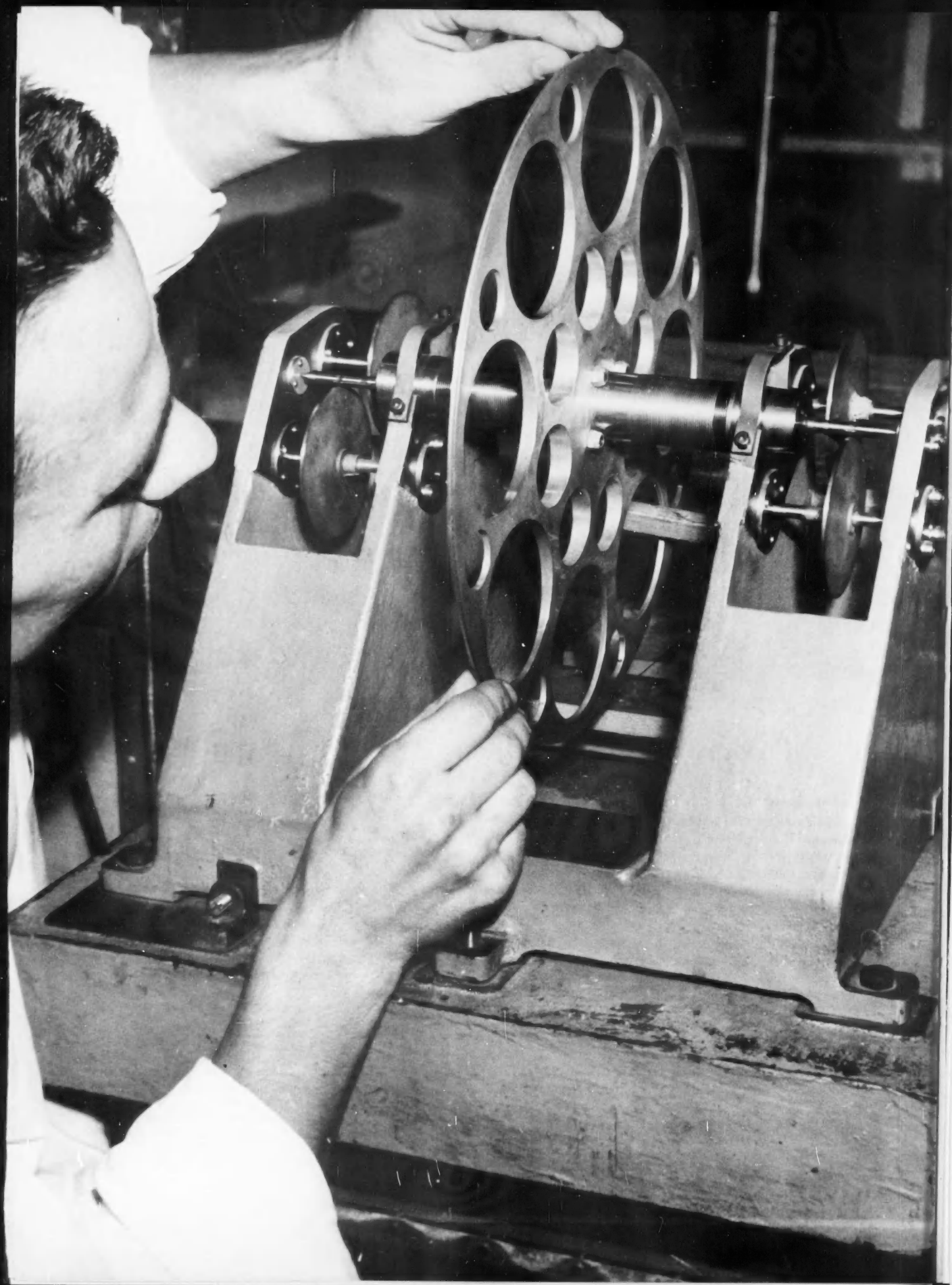

tech engineering news

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FRONTISPIECE

Pulleys and Wheels

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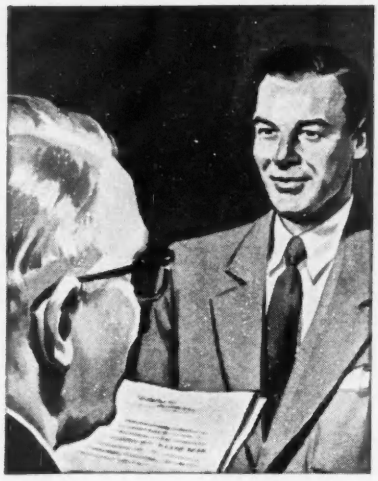

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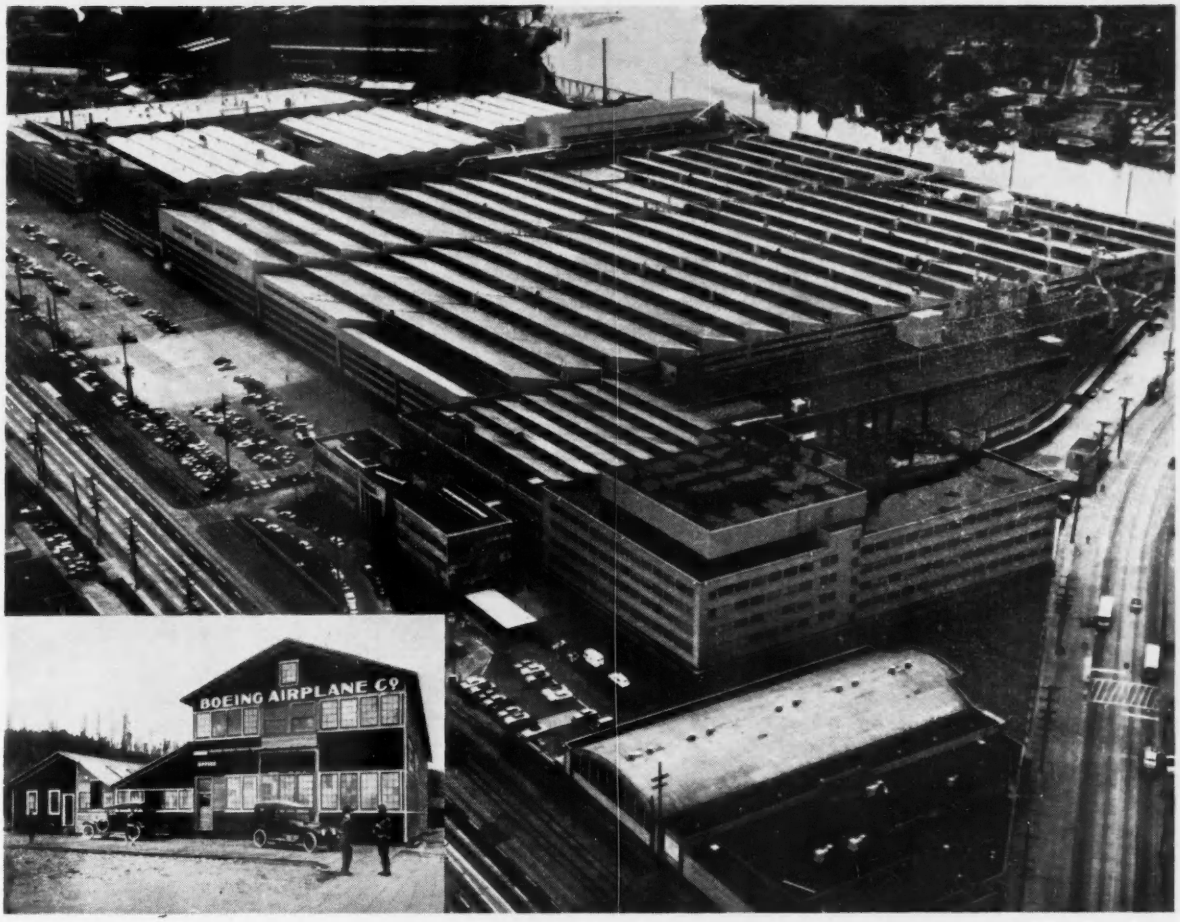

1916—The first Boeing plant, Seattle

1954—Boeing's Seattle plant as it appears today. New Engineering Building is shown in foreground.

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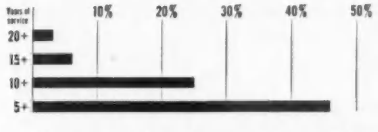

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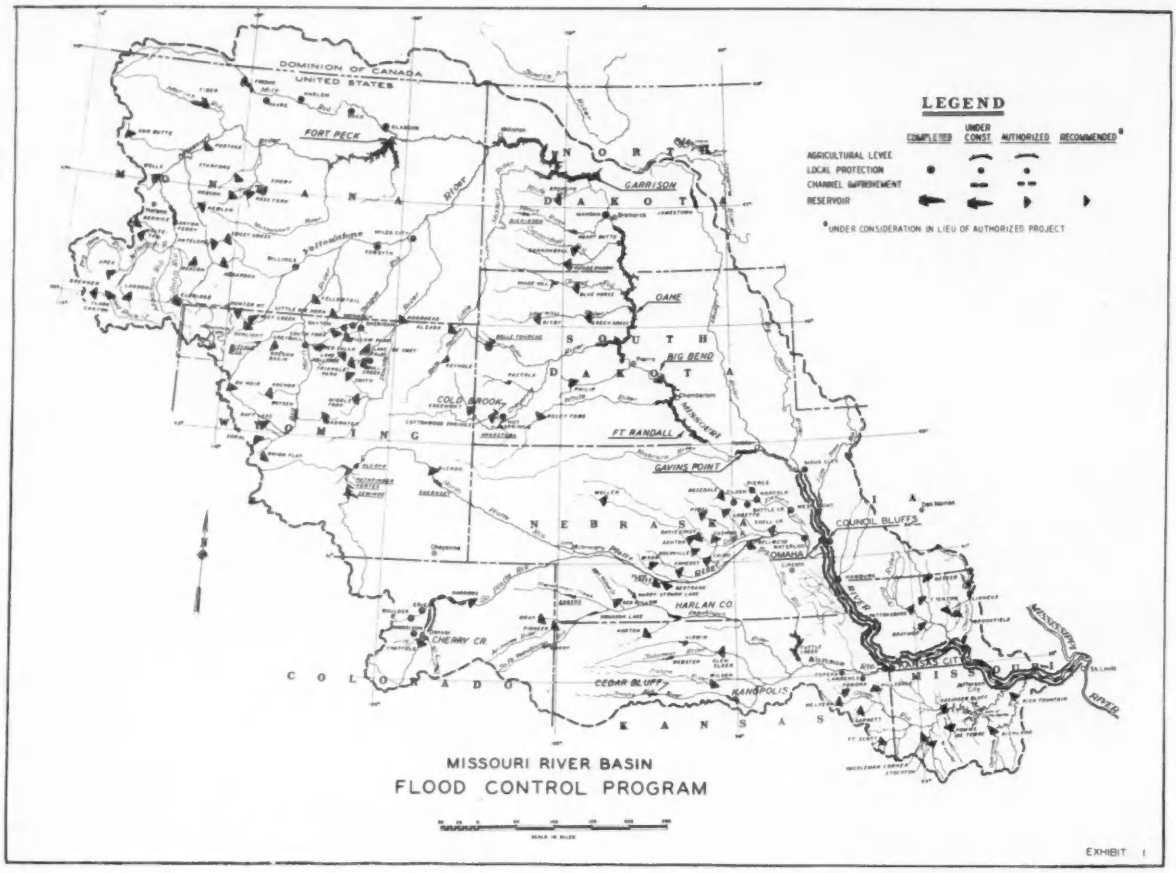
missouri river basin: problems and development

by Emmanuel P. Papadakis, '56



The magnitude of the Missouri River basin and the variety of geological and hydrological conditions prevailing within it are hard to comprehend. The area of the Missouri River basin is one-sixth that of the United States, about 500,000 square miles; the basin contains major portions of ten mid-western and northwestern states including Nebraska in its entirety and parts of Missouri, Kansas, Iowa, North and South Dakota, Montana, Wyoming, Colorado, and a slice of Minnesota. The climate varies from humid in the southeastern plains area to semi-arid in places further west and north. The topography is just as diverse; the eastern half of the basin is the Great Plains area while the western and southwestern region is in the Rocky Mountains along the Continental Divide. Parts of the basin lie in the Corn Belt and other parts in wheatland, cattle country, and mountain vacation lands. The average annual precipitation in the basin decreases from 42 inches at the mouth of the Missouri River at St. Louis, Missouri, to less than twelve inches in some of the semi-arid areas in the northwestern part, and then rises again in the mountains because of the heavy snows there. The extremes of altitude in the basin are 600 feet above mean sea level at St. Louis and 14,000 feet in the mountains. The slope of the channel of the Missouri River after leaving the mountains, varies from about eight-tenths to a foot per mile along the remainder of its length.

The drainage of the Missouri River is to the northeast in Montana and Wyoming, eastward and southward across the Dakotas, and to the southeast the rest of the way to the junction of the Missouri and the Mississippi Rivers. The work of the Wisconsin Glacier made the area above Yankton, South Dakota, suitable for building giant reservoirs by creating a deep channel through the high foothills in the area. Although this old channel is largely filled with alluvial earth while the river flows in a much smaller bed, the foothills remain to hold the water if dams are built between

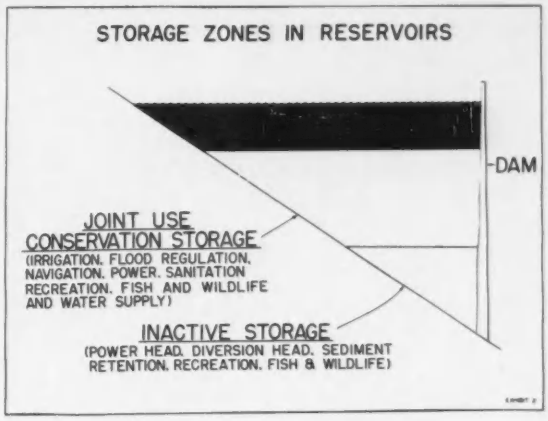
them. The lower valley is old and covered with rich soil making it an area generally much more productive than the upper valley. The population of the basin is concentrated in the lower valley on the excellent farm land and in the industrial-mercantile cities like St. Louis, the two Kansas Cities, St. Joseph, Omaha, and Sioux City.

The problems of the Missouri River basin arise from its topography, hydrology, climate, and industries; all the problems have one prime factor—water. In the area the water problems center around the Missouri River. The northwestern and western states in the basin have insufficient rainfall to sustain much farming; therefore crops in that region must be irrigated. The situation is completely reversed in the lower valley. There every year there is the danger of destructive floods —too much water. In such floods millions of dollars of damage is done to industries, farm land, and private property. On the other hand, there are times when so little water flows that the health and sanitation facilities of the river cities are in danger. Needless to say, navigation on such a capricious river must be irregular if not non-existent. Other problems such as the need for electrical power if the economy of the region is to grow must be faced in the Missouri River basin.

The obvious solution to the problems was to control the erratic Missouri River. But would this be possible? How much useful work could the river, once harnessed, do? What would the probable success of an attempt to control the river be? How much control would be economically feasible? These questions and many more had to be answered before any control operations could be instituted.

From the early days of United States history the building and maintenance of navigational facilities in rivers and harbors has been under the jurisdiction of the Army Corps of Engineers. Since the Corps of Engineers had already been working on minor navigational facilities on the lower reaches of the Missouri and since it was the logical group to handle the magnitude and interstate nature of the problems, the Corps was given more and more duties in the basin. These included responsibility for flood control as provided in the 1936 Flood Control Act.

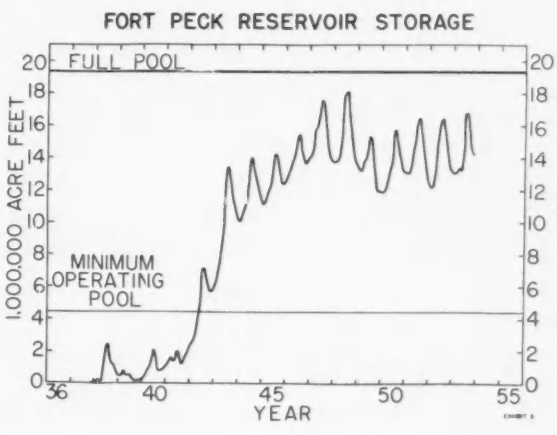
In the 1930's the first dam on the main stem of the Missouri River, Fort Peck near Glasgow, Montana, was built by the Army Engineers. Although the original purpose of the dam was to store water for navigation downstream, the capabilities of the dam were broadened by the building of a hydroelectric power plant at the site. The present comprehensive plan for the development of the water resources of the Missouri River basin was framed in the Flood Control Act of 1944, the famous Pick-Sloan plan. The Act of 1944 provided for the coordination of the activities of the Bureau of Reclamation and the Army Engineers in the Basin, and for the delineation of the spheres of influence of these two agencies. The scope of the work of the Army Engineers was enlarged to include flood control and the providing of water for irrigation, and for the production of hydroelectric power as well as for navigation. Specifically the Corps was authorized to build five more dams on the main stem of the Missouri River, to provide for a nine-foot deep navigation channel and erosion control


STORAGE ZONES IN RESERVOIRS
DAM
JOINT USE CONSERVATION STORAGE
(IRRIGATION, FLOOD REGULATION, NAVIGATION, POWER, SANITATION RECREATION, FISH AND WILDLIFE AND WATER SUPPLY)
INACTIVE STORAGE
(POWER HEAD, DIVERSION HEAD, SEDIMENT RETENTION, RECREATION, FISH & WILDLIFE)

project from Sioux City, Iowa, to the junction of the Missouri with the Mississippi near St. Louis, Missouri, and to build local flood protection facilities and agricultural levees along the same distance. The construction work on the dams alone including Fort Peck which is already completed will ultimately cost one billion dollars. Two of the new dams, Garrison and Fort Randall, are already in operation and will be finished shortly.

The Bureau of Reclamation is authorized to build many small reservoirs on the tributaries of the Missouri River. The primary function of these reservoirs will be to store water for irrigation, but flood control storage will be provided in most cases. Under flood conditions when the storage allotted to flood control in any reservoir is involved, the scheduling of the reservoir releases is turned over to the Corps of Engineers, so that the intricate work of prediction and control of floods is under the direction of one head. The nerve center of the reservoir system on the Missouri River is the office of the Missouri River Division of the U. S. Army Engineers which coordinates this function with the basin states and other Federal agencies.

The main stem dams on the Missouri River are built of compacted earth fill with concrete spillways, power tunnels, and other structures. As the comprehensive plan envisioned it, the function of the reservoirs is to store destructive flood waters



Ball-and-socket joint cast iron pipe for water main crossing river at Newark, Ohio.

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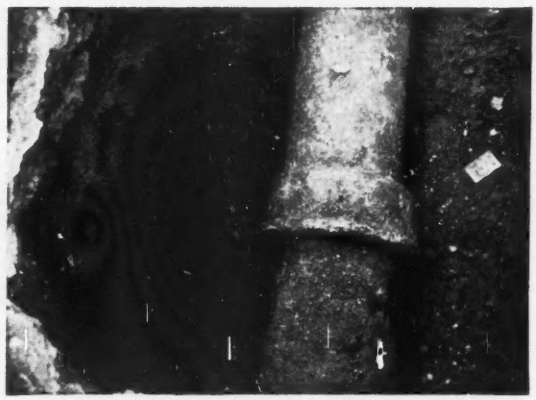
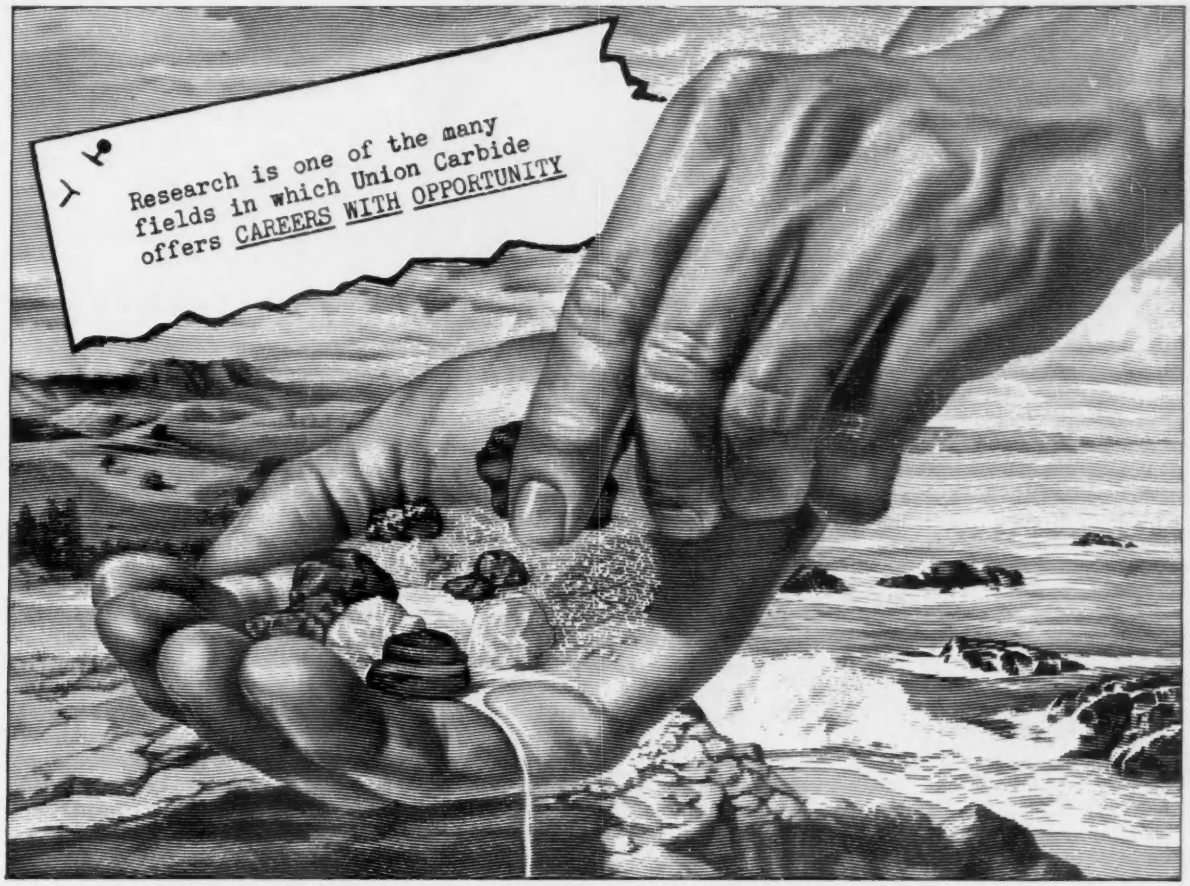


Cast iron water main still functioning in Philadelphia after 135 years of service.

CAST IRON PIPE SERVES FOR CENTURIES



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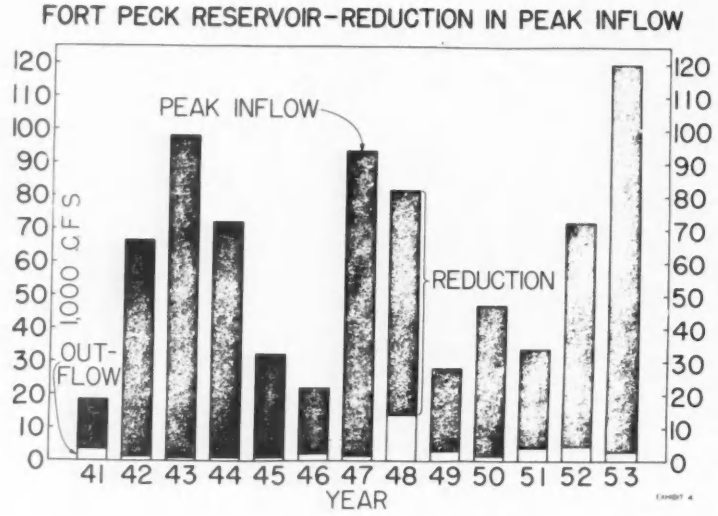

and to release the stored water when it is needed for navigation, irrigation, and power production. To this end the reservoirs are operated in the following manner: In each of them a certain volume of water is held in Inactive Storage to maintain the necessary pressure head for power production and irrigation diversions and to permit sediment retention, recreation, and the growth of fish and wildlife. A certain volume of storage space over and above this inactive minimum is reserved as Joint Use or Active storage. Water here is used for irrigation, navigation, flood regulation, production of power, sanitation, recreation, conservation of fish and wildlife, and municipal water supply. The remaining storage capacity is for flood control.

The water in Inactive Storage is never used under any circumstances, while the water allocated for Joint Use is released as needed. It is the function of the Joint Use part of the capacity of the reservoir system to store flood waters and excess runoff from year to year to provide surplus water in periods of drought. The main stem reservoir system was designed to hold enough water in Joint Use storage to supply the basin in a severe ten-year drought, such as that experienced in the 1930's. In such a period only navigation would be impaired by possible reduction of the normal navigation season. The storage capacity allocated to Flood Control is operated in two sections, the first kept partly full during the flood season and emptied gradually before winter and the second held empty for emergencies. This emergency part is emptied as soon as possible after a flood by releasing water fast enough to keep the river running at bank-full stage.

It is interesting to note that the total storage capacity in the reservoir system, 75 million acre-feet, is enough to store all the water passing Sioux City for three years.

There are tremendous problems encountered in operating such a tremendous reservoir system. One of the problems involves *travel time*, that is, the time necessary for water passing one point in the river to reach a point downstream. For instance, it requires seven days for water passing Yankton, South Dakota, (site of Gavins Point dam, now under construction) to reach Kansas City and twelve days to reach the mouth of the river. Suppose the emergency part of the Flood Control storage capacity at Gavins Point were being emptied making the river flow at bank-full stage. Within the next seven days heavy rains downstream from the dam could precipitate a major flood at Kansas City. Such a situation is entirely possible because run-off from the plains area in the spring and from the mountain snows in June is often of flood proportions and because heavy rains often occur in the lower basin at those times.

Concurrence of several flood-producing situations in different parts of the basin at different times can produce tremendous floods. By the same token, a series of water-storing events could cut down any flood to a size incapable of causing damage. One of the figures illustrates this ability very clearly, showing the effect the reservoir system could have made upon the flood of April, 1952, had all the reservoirs been completed then. The 1952 flood was caused by the rapid thawing of great quantities of snow lying on top of a hard-frozen crust of ice on the plains. Almost all the water from the snow-melt found its way to the river. The combination of flood walls and levees, millions of man-hours of emergency labor, and the storage in the Fort Peck reservoir saved the Omaha-Council Bluffs area from an estimated 61 million dollars' worth of damage. The Fort Peck reservoir is credited as having been indispensable in 1952, and since its completion in 1938 it has substantially repaid its cost in flood damage averted.

The flood of 1951 which caused so much havoc in Lawrence, Topeka, and Kansas City, Kansas, and in Kansas City, Missouri, was caused by incessant heavy rains in the Kaw River basin. The Kanapolis reservoir on the Smoky Hill River, a tributary of the Kaw, helped to reduce the damage at the cities listed.

The system of reservoirs on the Missouri River is required to supply part of the water needed to maintain the nine-foot deep navigation channel from Sioux City to St. Louis. Although the channel is not stabilized above Omaha as yet, the flow of water at Sioux City must be maintained at 30,000 cubic feet per second from March through November to satisfy downstream needs.

In 1954 the river carried 287,000 tons of cargo. The expenditure for navigation is economically feasible, for it is estimated that it will carry five million tons ultimately. At present there are six barge lines on the river: two common carries and four contract lines. Success for the navigation ventures is expected, for the precedent for it has been set by the traffic on the Mississippi River up to and down from Min-

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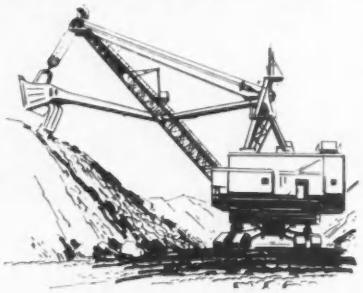
Culver City, Los Angeles County, California

Photograph above: Engineer-writer John Burnett (left) works with engineers John H. Haughawout (right) and Donald King to compile handbook information.

Keeping 3 million pounds on an even keel



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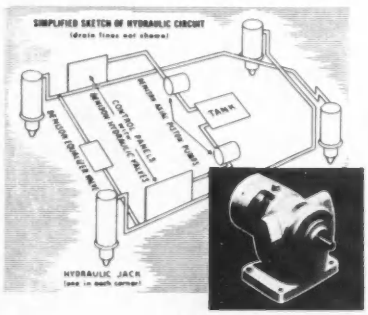

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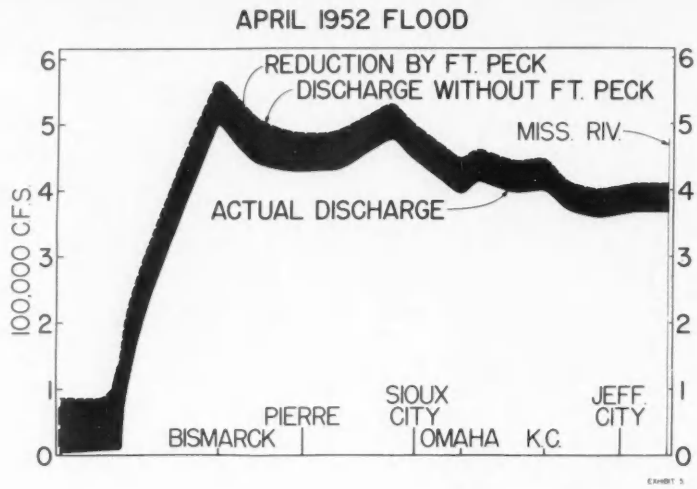

neapolis-St. Paul, the Illinois Waterway, and the Ohio River. All of these waterways are carrying more than the predicted traffic on which their economic justification was based. The detailed calculations performed before the Flood Control Act of 1944 was drafted showed that there would be sufficient traffic on the Missouri River to justify the expenditure on navigation projects and that there would be enough water in the reservoir system from storage of flood waters to sustain navigation on the river below Sioux City.

Part of the water used for navigation or dumped from Flood Control storage is used to produce hydroelectric power for the basin. This power has been a great boon to the area for use in farms and industry; more power will allow the productivity of the region to expand to the fullest possible extent. The power produced by the Corps of Engineers and marketed by the Bureau of Reclamation brought in revenue at the rate of about 1 million dollars a year in 1950. As more generators go on the line at the new reservoirs, that figure should be doubled, redoubled, and doubled again. By 1963, installed generating capacity should reach 1,500,000 kilowatts and revenues approach 40 million dollars.

Irrigation, too, will benefit from the main stem dams built by the Army Engineers. In 1940 there were 4,400,000 acres of land under irrigation in the basin. New land, 5,356,000 acres of it, can be supplied under the development program. Also, supplementary water will be supplied to 2,000,000 acres of land already under irrigation. The expanding agricultural production on irrigated land will help stabilize the economy of the upper basin and provide steady income for the many families whose jobs are presently affected by the unpredictability of their water supply.

As we have seen, the program of development in the Missouri River basin has helped the economy of the region and will help it more in the future by controlling floods, producing electric power, and providing water for irrigation and navigation. The Army Engineers are a key Federal agency in this program, and as such have great responsibilities in the basin. As their work progresses, in cooperation with the Basin States and other Federal Agencies, more and more people will feel the impact of the changes being made to harness the Missouri River for mankind.

Bill Zartman wants to know:

What effect would an advanced degree have on my opportunities for advancement at Du Pont?

William N. Zartman is studying for a B.S. in Chemical Engineering at the University of Illinois. Last summer he worked in the Technical Laboratory at Du Pont's Chambers Works to gain industrial experience. He has not yet selected a permanent employer, however; and right now he's asking the kind of questions which will help him select the right job and plan a successful career.

Dr. Sheldon Isakoff received his Ph.D. degree in Chemical Engineering from Columbia University in 1952, doing his graduate research work on the problem of heat transfer in liquid metals. Since graduation he's been engaged in fundamental research work at the Du Pont Experimental Station, Wilmington, Delaware. Dr. Isakoff is now a Research Project Engineer in the Engineering Research Laboratory.

Sheldon Isakoff answers:

An advanced degree would undoubtedly have a *favorable* effect in technical work, Bill, but let me enlarge on that just a little. In my own field—chemical engineering—a doctorate is considered to be evidence of demonstrated ability in carrying out original research. An advanced technical degree is therefore helpful in obtaining work in research and development, where that skill is definitely important. You might say it gives a man a head start in proving his ability in those areas.

It's less important in some other areas, though. For example, in production or sales work a manifest ability for handling human relationships is just as important for advancement as technical competence. If an engineer is sold on production work or sales, a graduate degree in marketing or business administration might be more helpful to him than advanced technical training—in getting started.

But I've noticed this at Du Pont. Once a man lands a job in his chosen field and actually begins to work, his subsequent advancement depends more on demonstrated ability than on college degrees. That's true throughout the entire company—in scientific work, administration, or what not.

So an advanced degree is not a royal road to anything at Du Pont, Bill. But when coupled with proved abilities, an advanced technical degree is unquestionably helpful to a man in research and development work. It often gives him a chance to demonstrate his abilities more rapidly.

Are you interested in research work?

About 2000 Du Pont scientists are currently engaged in research, aided by some 3500 other employees. Laboratory facilities of the highest quality are available at the Du Pont Experimental Station near Wilmington, and elsewhere throughout the country. Full information about research work at Du Pont is given in "The Story of Research." Write for your copy of this free 28-page booklet to E. I. du Pont de Nemours & Co. (Inc.), 2521 Nemours Building, Wilmington, Delaware.

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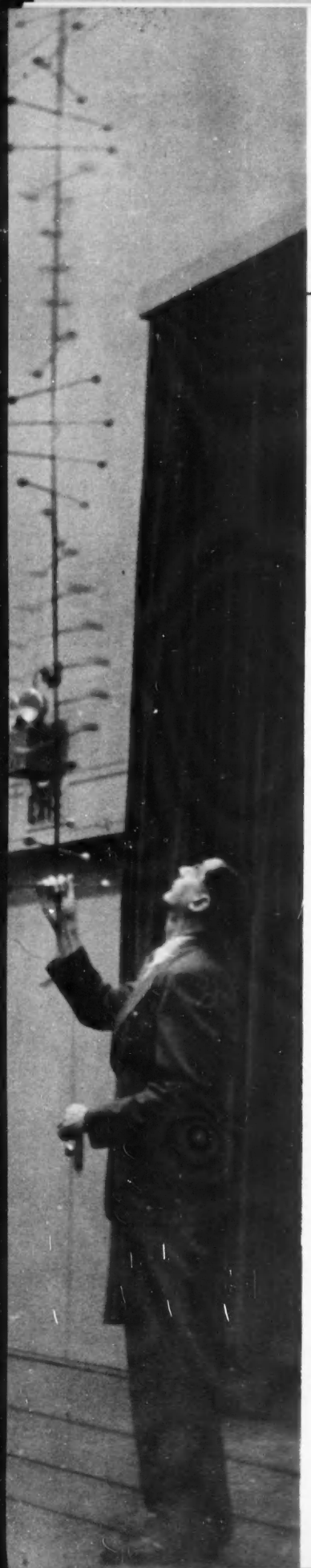

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from the editor's notebook

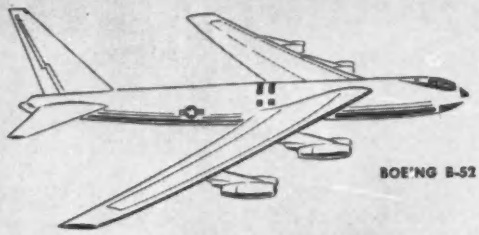
In the second week of June 1954 the Supreme Court surprisingly reversed (vote was 5 to 3) the decision that the Federal Power Commission (F.P.C.) had made in 1951. The F.P.C., before June, had held that they exercised no authority to regulate the price of natural gas at the wellhead, but now, since the ruling on the Phillips Petroleum case, they have to enforce, in Orders 174 and 174a, a power which they do not want. Politically, it is a war between the consumer and the producer. The consumers argue that gas prices cannot be properly controlled unless the sale of gas from the well to the pipeline is regulated. The producers say that contrary to popular thought the price of natural gas will rise if the production price is regulated, and the producers hope to prove their point to the consumers in time to pass favorable legislature this month in both houses.

A recapitulation of the gas industry shows that most of the natural gas comes from our major oil fields. Approximately 4100 independent producers are supplying the energy needs of our nation. The independent producers sell their gas to the pipelines, which are regulated, and they in turn supply the gas to the consumer. As in numerous other goods, the major cost of gas to the consumer consists of handling and distribution charges, whereas, less than ten percent of the total cost is, on the other end of the pipeline, paid to the producer. It is important, therefore, to point out that regulation of the producer will result in no appreciable change in price to the consumer. In fact even if regulation were successful in effecting a ten per cent decrease in price at the wellhead, the resulting decrease to the consumer would be less than one percent.

Why are the pipelines regulated and the producers not? The piplines have two important privileges; the right of eminent domain and the privilege of semi-monopoly. Prospective pipeline builders submit to the governmental authorities their plans, estimated costs, etc. Upon approval they may lay their pipeline across a man's property, whether he likes it or not, with a guarantee of payment to the landowner by arbitration. Once the line is in, no other pipeline is allowed, unless the demand for gas warrants expansion. Although the pipeline rates are regulated the rates are such that, through a period of years, the capital is returned and usually a six per cent return on the investment is realized. These rights and privileges are not available to the producers. They do not have a semi-monopoly or the right of eminent domain; and they should not have. The producer must rely upon his own capital to find and exploit natural gas. Even with all the scientific aids of modern geology, finding such reservoirs is a risky business since the present success ratio is one to nine (the average hole costs approximately $100,000.00). How could a regulating body fairly set rates for 4100 independent producers, whose luck sometimes fails in a series of dusters? Regulation of this sort would entail a bureaucracy to end all bureaucracies. Such regulation, if attempted, would force the producers to reduce exploration costs, which would finally result in less production and smaller reserves. This procedure would be unwise at a time whe nour reserves are being alarmingly depleted, while our consumption continues to increase. In 1946 our estimated reserves were adequate for thirty-two years, while in 1953 we had only a twenty-three year reserve. Also, in the last ten years the use of gas for our nation's energy needs has doubled. Gasmen have already talked of a sharp cutback in new exploration and drilling, rather than take the great risks entailed with little profit. Clearly, from this viewpoint alone the regulation of gas producers would be inadvisable, for a reduction in supply would certainly result in an increase of price.

At this moment the price of gas is controlled by the price of other energy commodities, such as coal and oil. If the price of one of these were to increase, the usage of the others would become popular. A natural set-up of checks and balances is thereby maintained. If the price of one were regulated it would be but a matter of time before the others were. How could government regulation, slow in reaction-time, possibly cope with the naturally balancing fluctuations of price? How could government regulation be flexible in order to meet normal fluctuations? No such artificial regulation is possible. Nor should we want such regulation. Regulation has a place in our economy. When a few large corporations control the motion of a nation, those corporations should be supervised, but when legislation is intended to govern 4100 independent gas producers, then the government is needlessly hobbling the nation's economy.

K. R. K.



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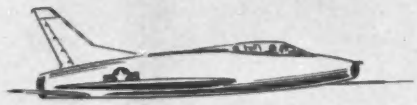

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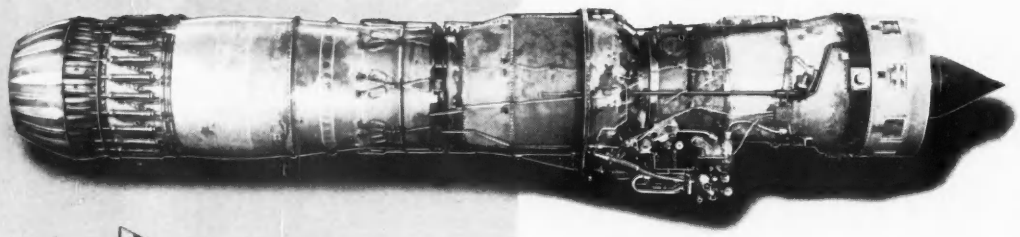

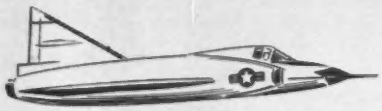

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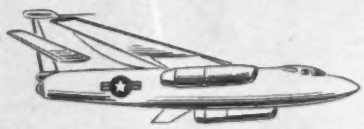

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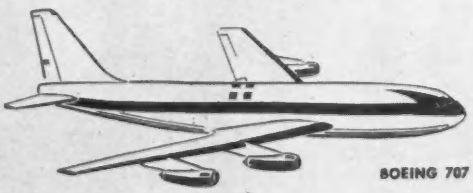

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special theory of relativity

by Neil MacFarlane, '58

Introduction

Relativity, like light, time, arithmetic, and many other things, is something which everybody can talk about and work with, and yet something which few people can understand. For example, we all learned to use arithmetic in the early grades without ever having had any preparatory courses in number theory. Similarly, this article will make no attempt to lay bare the deep philosophical implications of the special theory of Relativity (mainly because the author doesn't understand them himself), but will merely give a simple method by which anyone, with an understanding of high school algebra, can derive these equations for himself.

Because we will be limiting ourselves to lower mathematics, some of the algebra involved will become quite messy, although it will still be straightforward and understandable. The other disadvantage in using lower mathematics will be that the derivations of some of the equations will not be as rigorous as they might be with higher mathematics. In fact a really critical reader, especially one with an understanding of the philosophy of relativity and of higher mathematics will be able to tear parts of this article to pieces. For example, the mathematical device most used in this article will be the cartesian coordinate system, and yet how do we know that this method of describing points in space is valid under all conditions? We don't know, and we don't know enough to prove it either, so we will have to accept it.

With these things in mind, let us proceed to see how length, time, and mass in one reference system are related to length, time, and mass in another reference system, which is the main subject of the Special Theory of Relativity.

Part I. Basic Ideas and Assumptions

One of the tacit assumptions which classical physics makes, and one which Einstein had the genius and courage to doubt was that time was an invariant quantity in the universe. The classical physicist would say that fifteen seconds is fifteen seconds long whether it is measured by someone standing on the ground or by someone flying in an airplane at a velocity v with respect to the ground. It turns out, as we shall soon see, that Einstein was correct in not assuming that time is not invariant. In fact, the fifteen seconds is longer in the airplane than on the ground.

Since we aren't going to be able to assume that time is invariant, we will have to introduce it into our calculations as a fourth variable. In mathematics, the physical significance of a dimension is a variable. If we have four variables, we have four dimensions. Our physical space is therefore four dimensional. Three of these dimensions are spatial, and one is temporal. (That is, we measure space along three of them and time along one of them.) We already have the convention of representing the first three dimensions by the X, Y, and Z axes. Let us represent the fourth dimension by the W axis. Then a point in our four dimensional coordinate system would be uniquely described by the coordinates (x, y, z, w). A question which wouldn't occur to most people is should we make this fourth dimension pure time, or some function of time? It would seem only natural to make the W axis measure pure time so that we would mark off on the W axis units of time, like seconds, just as we mark off on the X, Y, and Z axes units of length, like feet or meters. However, it turns out to be much more fruitful to call the W axis not pure time, but cit, the product of the speed of light (c), the square root of minus one (i), and time (t). This fact may be rather hard to accept on faith, so the following argument is offered to convince the reader.

Figure 1 represents two systems of reference S and S′ with observers in them. S′ is moving with a velocity v with respect to the S system. (S′ may be an airplane or something.) Point P represents an event, since its position in space is given by the x, y, and z coordinates of the point, and the time at which it is happening is given by its w coordinate. An observer in the S system would describe point P by the numbers x, y, z, and w, while an observer in the S′ system would describe point P by the numbers x′, y′, z′, and w′. (Notice that we are not

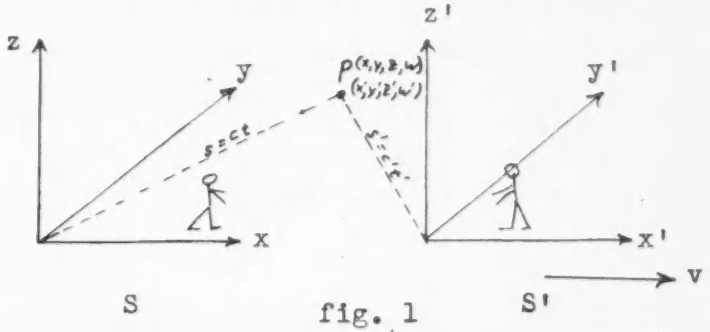

fig. 1

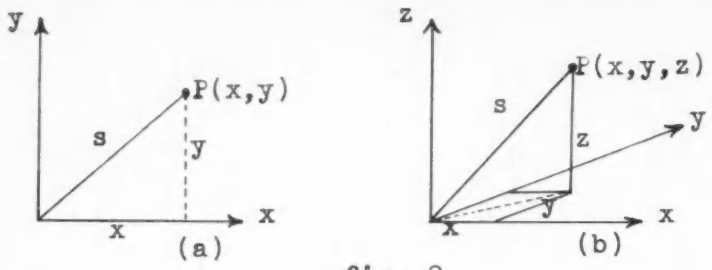

fig. 2

assuming w=w′, or in other words, that the event appeared to happen at the same time for both observers.) If the observers were at the origins of their reference systems, the distance s from them to the point P would be ct, since they would be observing P by the light which comes from it, and since distance=velocity X time, s=ct for the S system, and s′=c′t′ for the S′ system. At this point we make the fundamental assumption of the Special Theory of Relativity, namely, that the speed of light is an, in fact *the* invariant quantity of the universe.* Therefore, c=c′ and hence s=ct and s′=ct′. Now then, what relation exists between x,, y, z, w, and s and also between x′, y′, z′, w′, and s′? This question is easily answered by the theorem of Pythagoras.

In a two dimensional space, fig. 2a, $s^2=x^2+y^2$. In a three dimensional space, fig. 2b, $s^2=x^2+y^2+z^2$, as can be easily shown by applying the Pythagorean Theorem twice. It follows by analagous reasoning (which is dangerous) that in a four dimensional space,

$$s^2=x^2+y^2+z^2+w^2$$

If the observers in the S and S′ systems use the 3D version of the Pythagorean Theorem on their data concerning the special coordinates of P, they will get respectively

$$\text{and} \quad \begin{cases} s^2=x^2+y^2+z^2 \\ s'^2=x'^2+y'^2+z'^2 \end{cases}$$

and since s=ct and s′=ct′,

$$\text{and} \quad \begin{cases} c^2t^2=x^2+y^2+z^2 \\ c'^2t'^2=x'^2+y'^2+z'^2 \end{cases}$$

$$\text{or} \quad \begin{cases} x^2+y^2+z^2-c^2t^2=0 \quad (1) \end{cases}$$

$$\text{and} \quad \begin{cases} x'^2+y'^2+z'^2-c\,t'^2=0 \quad (2) \end{cases}$$

Notice that equations (1) and (2) have the same form as

$$x^2+y^2+z^2+w^2=s^2$$

provided that the s^2 of this equation equals 0. (That is, the observer is at the origin of this 4D coordinate system.) Therefore, if an observer is at the origin of a 4D coordinate system, then

$$x^2+y^2+z^2+w^2=0$$

but $x^2+y^2+z^2-c^2t^2=0$

Therefore $w^2=-c^2t^2$ and so w=cit Q.E.D.

Now that we have discussed a four dimensional coordinate system, and have shown that the fourth dimension must be cit, we are prepared to go into the Lorentz Transformation, which is the magic key to relativistic physics.

*This statement means that if a source of ligth were coming toward you with say ½ the speed of light, and the light itself was coming from the source with the speed of light, then the light would be coming toward you with only the speed of light, and not 1½ times the speed of light, as we would ordinarily expect. This postulate has considerable experimental verification. For example, the light coming from a double star would not behave as it does if the speed of light varied with the speed of its source. It should be pointed out however, that this postulate applies only to light propagated through the same medium. It is a well established fact that light slows up when passing from one medium to another of greater density. This explains the refractive powers of various transparent substances such as glass and water.

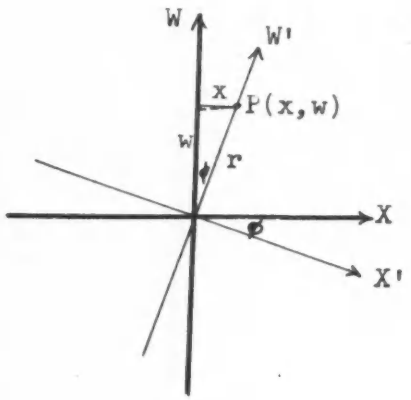

fig. 3

Part II The Lorentz Transformation

Referring to figure 1, we see that we have two sets of information concerning point P. This information in the S system is x, y, z, and w, but in the S′ system, it is x′, y′, z′, and w′. The problem set before us is to find a relationship between x and x′, y and y′, z and z′, and w and w′. We can simplify the relations between the y's and z's by letting the S′ system move in such a way that the x axes are coincident, and the y and z axes are respectively parallel to the y′ and z′ axes, as is shown in figure 1. Then obviously y=y′ and z=z′, since these coordinates of P never change as S′ moves along the x axis. Therefore, we will only need to concern ourselves with the problem of finding a relation between x and x′ and w and w′.

We now need a convenient and concrete way of expressing geometrically the relative velocity between the primed coordinate system and the unprimed coordinate system. Perhaps the easiest way of doing this is to superimpose the primed system on the unprimed system so that their origins coincide, and then represent the relative velocity between them by the amount of rotation of one system with respect to the other. Figure 3 makes this clear.

The size of angle ϕ is a measure of the velocity between S′ and S. (The Y and Z axes have been left out of this diagram, since it would only clutter things up to try to draw a perspective of a four dimensional coordinate system on a two dimen-

sional surface. We are no longer interested in the Y and Z axes anyway, since we now know that the relation between them is one of simple equality if the S′ system is moving with respect to the S system in the way described above.) In order to find the exact functional relationship between ϕ and v, take any point P on the W′ axis and call its coordinates with respect to the unprimed system x and w. Hhen by simple trig, $\sin\phi = x/r$ and $\cos\phi = w/r$. But by the Pythagorean Theorem, $r^2 = x^2 + w^2$ and since $w = cit$, $r^2 = x^2 - c^2t^2$ but $x = vt$ so $r^2 = v^2t^2 - c^2t^2 = -t^2(c^2 - v^2)$

$$r^2 = c^2t^2\left(1 - \frac{v^2}{c^2}\right)$$

therefore,

$$r = cit\sqrt{1 - \frac{v^2}{c^2}} = w\sqrt{1 - \frac{v^2}{c^2}}$$

substituting for r, $\sin\phi = \dfrac{x}{cit\sqrt{1 - \frac{v^2}{c^2}}}$ or, since $x = vt$,

$$\sin\phi = \frac{vt}{cit\sqrt{1 - \frac{v^2}{c^2}}} = -\frac{vi}{c\sqrt{1 - \frac{v^2}{c^2}}} \qquad \boxed{\sin\phi = \frac{-vi}{c\sqrt{1 - \frac{v^2}{c^2}}}}$$

In like manner, $\cos\phi = \dfrac{\omega}{\omega\sqrt{1 - \frac{v^2}{c^2}}}$

$$\boxed{\cos\phi = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}}$$

We now have ϕ expressed in terms of v.

Figure 4 represents the S and S′ systems as in figure 3. Point P represents an event which is described by an observer in the S system by the numbers x and w and by an observer in the S′ system by the numbers x′ and w′. The problem of finding x′ in terms of x and finding w′ in terms of w is now nothing more than a problem of transformation of coordinates. Looking at the figure, we see that OA = OB — AB = OB — CD. It is easy to see by geometry that the little angle up at P is ϕ. Therefore, we see by trig that OB = x cosϕ and CD = w sinϕ. And since OA = x′, we have x′ = x cosϕ — w sinϕ.

Substituting into this the values of sinϕ and cosϕ, we get

$$x' = \frac{x}{\sqrt{1 - \frac{v^2}{c^2}}} - cit\left(\frac{-vi}{c\sqrt{1 - \frac{v^2}{c^2}}}\right)$$

$$x' = \frac{x + i^2tv}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Therefore, $\boxed{x' = \dfrac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}}$ (3)

Similarly, from the figure, PA = PD + DA = PD + CB
Since PA = w′, PD = w cosϕ, and CB = x sinϕ,
w′ = w cosϕ + x sinϕ

$$\omega' = cit' = \frac{cit}{\sqrt{1 - \frac{v^2}{c^2}}} + x\left(\frac{-vi}{c\sqrt{1 - \frac{v^2}{c^2}}}\right) = \frac{cit - \frac{vxi}{c}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Therefore, (4)

$$\boxed{t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}}$$

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Equations (3) and (4) are the Lorentz Transformation equations. We now have the relation between x′ and x and between t′ and t that we were looking for. With these equations, we are at last ready to unlock the door to the marvels of relativistic physics.

Part III Relativistic Length—Contraction in Direction of Motion.

It is very difficult for most people to believe that a body in motion contracts in the direction of its motion. The only reason this seems strange, is just because we've never experienced such a contraction before. The reason nobody has ever experienced this contraction before is because nobody has ever been able to produce velocities great enough to make this contraction noticeable.

Let us now show mathematically that a contraction does occur, and also find out quantitatively to what extent this contraction takes place.

A person in the moving S′ system has a stick. To him, the stick appears to be at rest, and he measures its length to be 1_0. What length 1 does this stick appear to be to an observer in the S system? Let us have the observer in the S′ system place the stick on the X′ axis so that the coordinates of its ends will be $(x'_1,0)$ and $(x'_2,0)$. Then, by equation (3) of the Lorentz Transformation,

$$\begin{cases} x'_2 = \dfrac{x_2 - vt}{\sqrt{1-\frac{v^2}{c^2}}} \\ x'_1 = \dfrac{x_1 - vt}{\sqrt{1-\frac{v^2}{c^2}}} \end{cases}$$

subtracting, $x'_2 - x'_1 = l_0 = \dfrac{x_2 - vt - x_1 + vt}{\sqrt{1-\frac{v^2}{c^2}}} = \dfrac{x_2 - x_1}{\sqrt{1-\frac{v^2}{c^2}}} = \dfrac{l}{\sqrt{1-\frac{v^2}{c^2}}}$

solving for 1, $\boxed{l = l_0\sqrt{1-\frac{v^2}{c^2}}}$

Since v is not zero, $\sqrt{1-\frac{v^2}{c^2}}$ is always less than one, or else imaginary, the length of 1_0 will appear to an observer in the S system to be shortened by an amount $\sqrt{1-\frac{v^2}{c^2}}$. Let us take a specific example. Suppose we had a space ship which is 100 feet long and is traveling at four fifths the speed of light. How long does the ship appear to be to an observer at rest relative to the space ship?

$v = 4/5\ c$

$1_0 = 100$ ft.

so

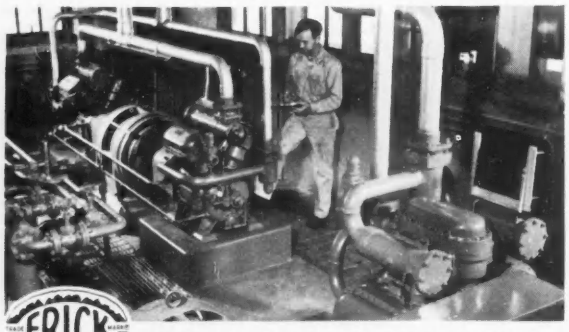
$$l = l_0\sqrt{1-\frac{v^2}{c^2}} = 100\sqrt{1-\frac{16c^2}{25c^2}} = 100\sqrt{\frac{9}{25}} = \frac{100 \cdot 3}{5} = \boxed{60 \text{ ft.}}$$

We see that the space ship has contracted 40 ft. Suppose the ship had been going exactly the speed of light. Then $l = 100\sqrt{1-\frac{c^2}{c^2}} = 100\sqrt{0} = \boxed{0 \text{ ft}}$. Now the ship has no length at all! Supposing the ship were going faster than the speed of light; then v^2/c^2 would be greater than one, and so the quantity under the radical would be negative, and hence the ship would have an imaginary length. Since an imaginary length doesn't seem to have any physical significance, we may conclude that nothing can go faster than the speed of light. However we will meet a stronger argument that nothing can go faster than the speed of light, or even as fast as the speed of light in Part VI on Relativistic mass.

Why has classical physics been so successful, if lengths vary with their velocity? The answer is of course that in our everyday lives, the velocities we encounter are so small compared to that of light that v^2/c^2 for all practical purposes is zero. Then we see that the expression for relativistic length reduces to the one common to our experience, namely $1 = 1_0$.

Part IV Relativistic Time—Dilation of Time.

Besides length, time also is affected by velocity, as is readily seen from equation (4) of the Lorentz Transformation. Supposing our observer in the S′ system puts a clock at the origin of his



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reference system. Then the x′ coordinate of the clock will always be zero in the s′ system. Then the x coordinate of the clock in the S system can be found from equation (3) of the Lorentz Transformation:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

If $x' = 0$,

$$\frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} = 0$$

and so $x = vt$

Now by equation (4) of the Lorentz Transformation,

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

and since $x = vt$ if the clock is at the origin of the S′ system, we get

$$t' = \frac{t - \frac{v^2 t}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{t\left(1 - \frac{v^2}{c^2}\right)}{\sqrt{1 - \frac{v^2}{c^2}}} = t\sqrt{1 - \frac{v^2}{c^2}} \qquad t' = t\sqrt{1 - \frac{v^2}{c^2}} \; -$$

The observer in the S′ system now reads a time interval on his clock, say from $t' = t'_1$ to $t' = t'_2$. The observer in the S system is also watching this same clock and he records the interval to be from $t = t_1$ to $t = t_2$. Let us denote rest time, $t'_2 - t'_1$, by t_0 and the same time when measured by an observer in the S system, $^{o}t_2 - t_1$, by t. Then we have from the equation above,

subtracting,

$$\begin{cases} t'_2 = t_2\sqrt{1 - \frac{v^2}{c^2}} \\ t'_1 = t_1\sqrt{1 - \frac{v^2}{c^2}} \end{cases}$$

$$t'_2 - t'_1 = t_0 = t_2\sqrt{1 - \frac{v^2}{c^2}} - t_1\sqrt{1 - \frac{v^2}{c^2}} = (t_2 - t_1)\sqrt{1 - \frac{v^2}{c^2}} = t\sqrt{1 - \frac{v^2}{c^2}} \; -$$

hence

$$\boxed{t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}}$$

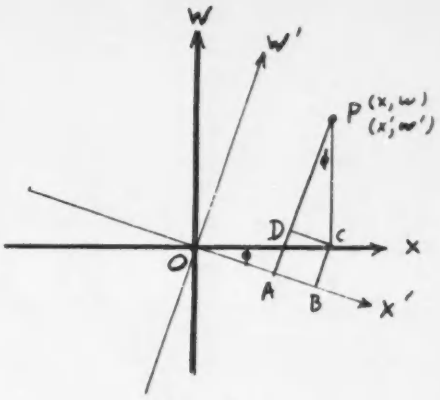

fig. 4

We see that the factor which makes time in relativistic physics differ from time in classical physics is just the reciprocal of the factor which makes relativistic lengths differ. As can easily be seen from the equation above, the greater v becomes, the greater t becomes. In fact if v=c, then this means that time has stopped altogether by the time v reaches c. But unfortunately for the science fiction enthusiast, time doesn't begin to go backwards for velocities greater than c, but instead becomes imaginary.

Here, as in the case of relativistic length, we notice two things: one; the speed of light seems to be a limiting velocity, and two; the reason for the success of classical physics is that v^2/c^2 is usually so small that the time dilations produced are negligible—in fact immeasurable.

Experimental verification of this part of the Special Theory of Relativity has been quite simply achieved by noticing that certain atomic particles live longer when moving at high velocities. The lifetime of these particles, usually mesons, while at rest is a characteristic constant of the particles. Since the lifetime of the particles can't be changed, the only thing that must have been slowed down was the progression of time itself.

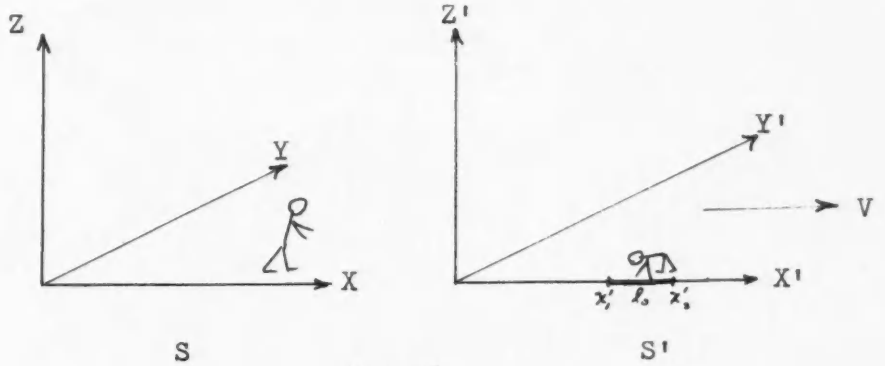

fig. 5

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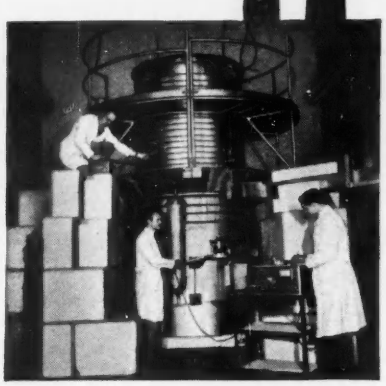

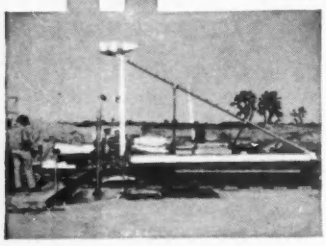

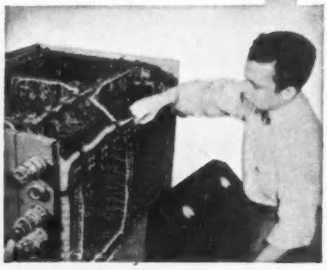

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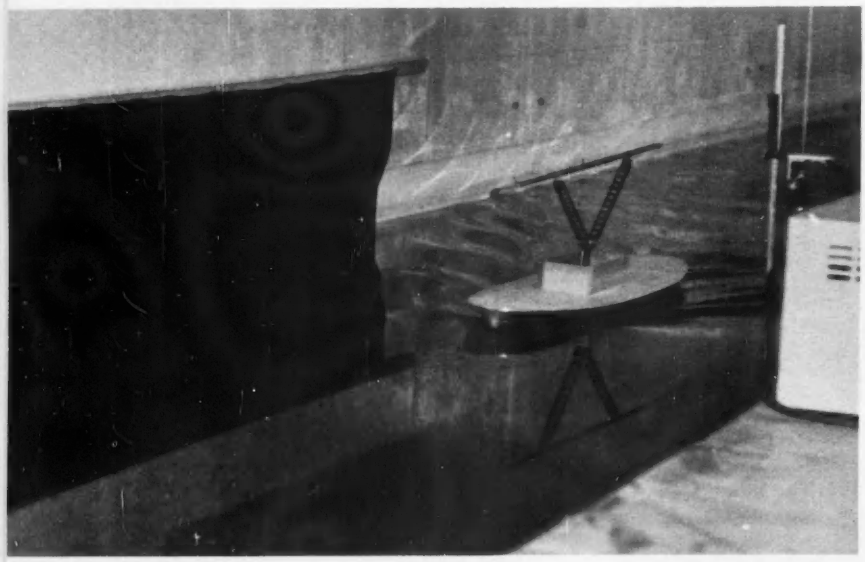
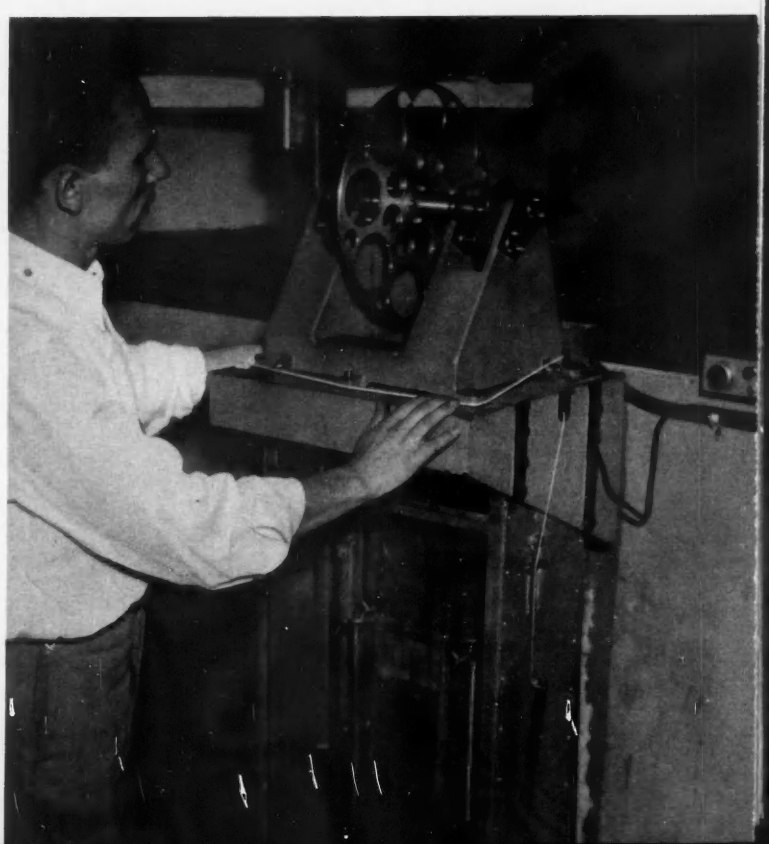
the hydrodynamics laboratory

by Malcolm A. MacLeod, '55

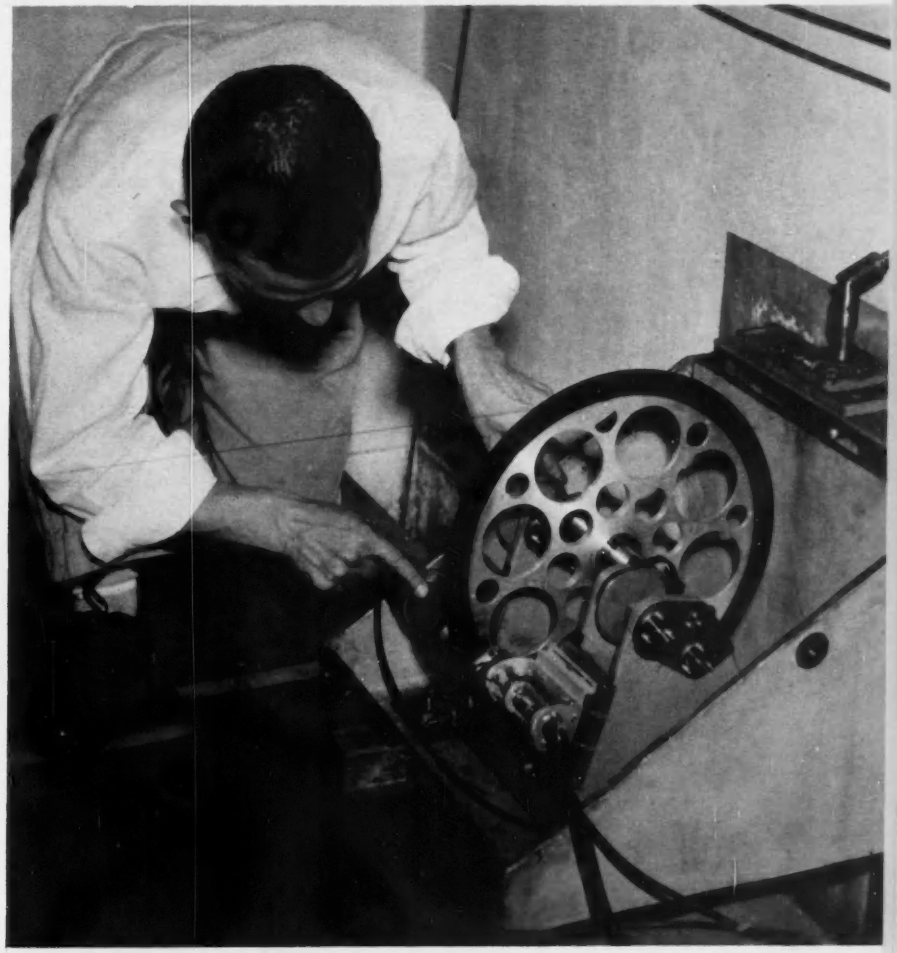
The pictures on this page represent the photographer's impressions of a visit to the towing tank located in the hydrodynamics lab in building 48. They are far from being a comprehensive coverage of the activities there, but perhaps will serve to show how modern scientific research methods are used in the present-day stage of an age old problem, the design of better ships.



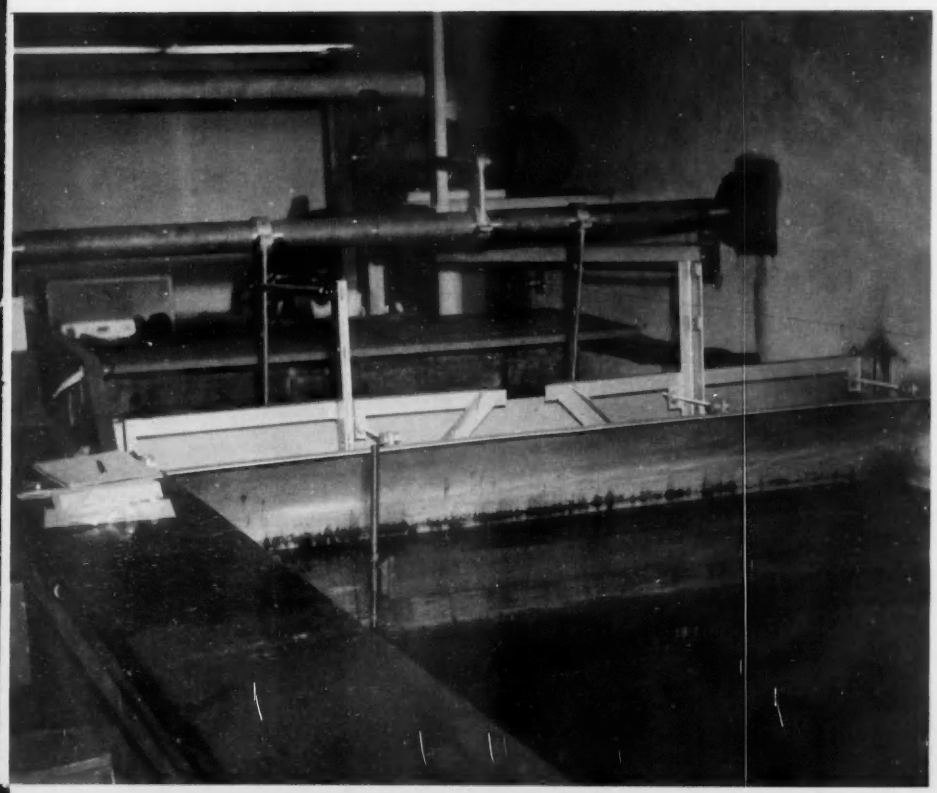
A ferry boat model undergoing a still water run. The model is guided along the center of the tank by a wire attached to the bracket amidship. The seaworthiness and stability of the models can be determined from the various tests done on them.



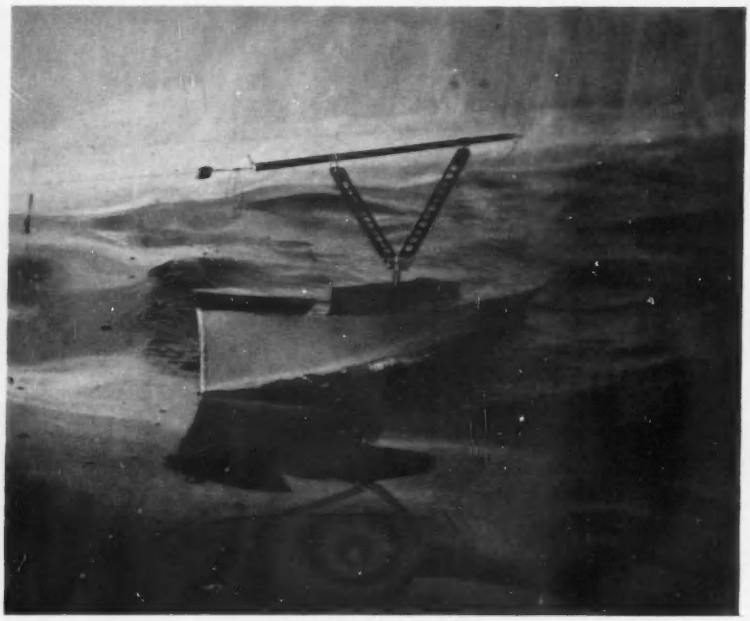
One of the two main guide pulleys is checked by Wachnik. A system of weights and pulleys is used to propel the models, whose speed may be measured to an accuracy of 1/1000 of a knot by means of electronic apparatus. (See frontispiece for a close-up of the pulley system.



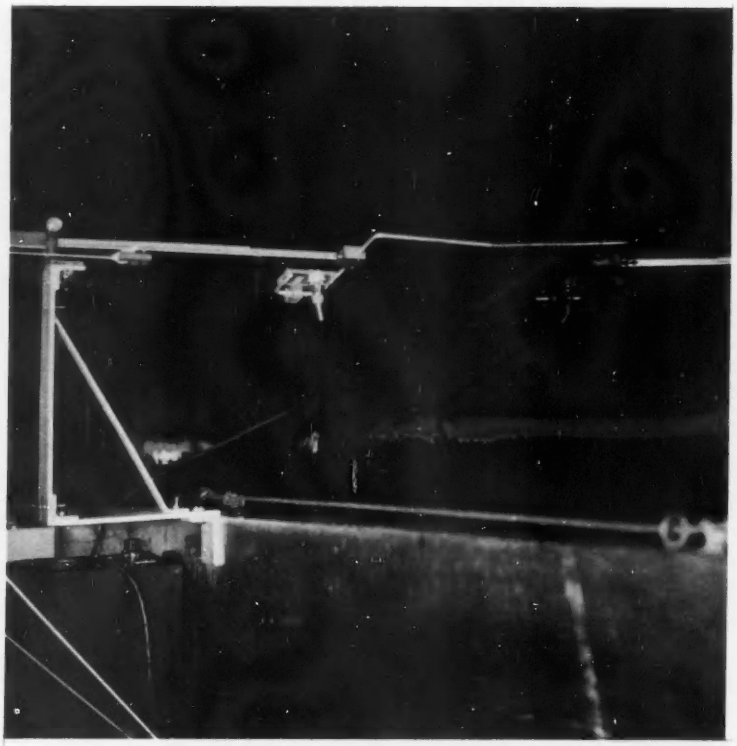
A rim attached to the second main guide pulley has 2,000 small slits along the edge through which a light is directed on a phototube, which Mr. Wachink is pointing to. The number of slits going by per second is directly proportional to the velocity of the model, which may thus be determined by means of an electronic integrating circuit.



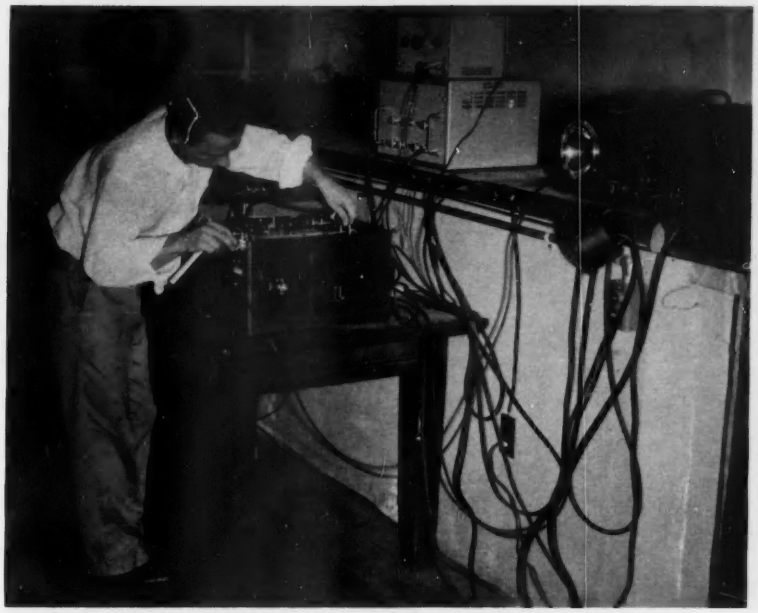
This machine makes waves in the tank for tests under a variety of conditions. The wavelength may be adjusted by varying the speed of the motor in the background, and the amplitude may be varied by changing the eccentricity of the cam-mounted driveshaft.



One of the models undergoing a rough water test. The waves in this case are quite large, since the wavelength is comparable to the ship's length. Notice the turbulence in the water immediately next to the hull. Since these models have quite smooth hulls compared to the actual ships, ordinarily no turbulence would be present, but it is produced by a rough strip cemented to the prow.



A close-up of the probe part of a new device for measuring the wave shape as a function of time. The portion of the probe immersed in the water is adjustable, but fixed for any one series of readings. The immersed section is heated electrically and the heat dissipated during any instant is proportional to the length of the immersed section.



Electrical apparatus used in conjunction with the precing probe for plotting the wave shape. Also visible is a stroboscope in the upper right which is used with a photographic recording system for studies of the seaworthiness of the models. The models are pulled past a black cloth (visible in the first picture) with a graduated white stick mounted vertically. A time exposure made while the stroboscope flashes shows how the ship responds to rough water by the motion of the graduated stick.

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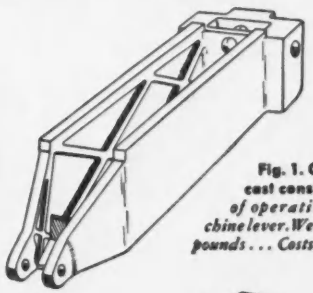
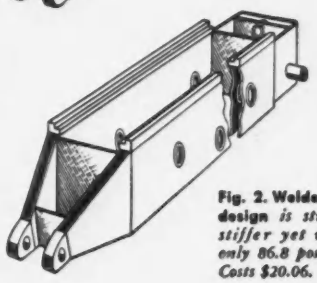


Fig. 1. Original cast construction *of operating machine lever. Weighs 182 pounds . . . Costs $38.25.*



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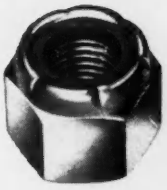

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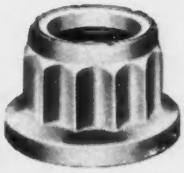

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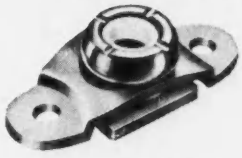

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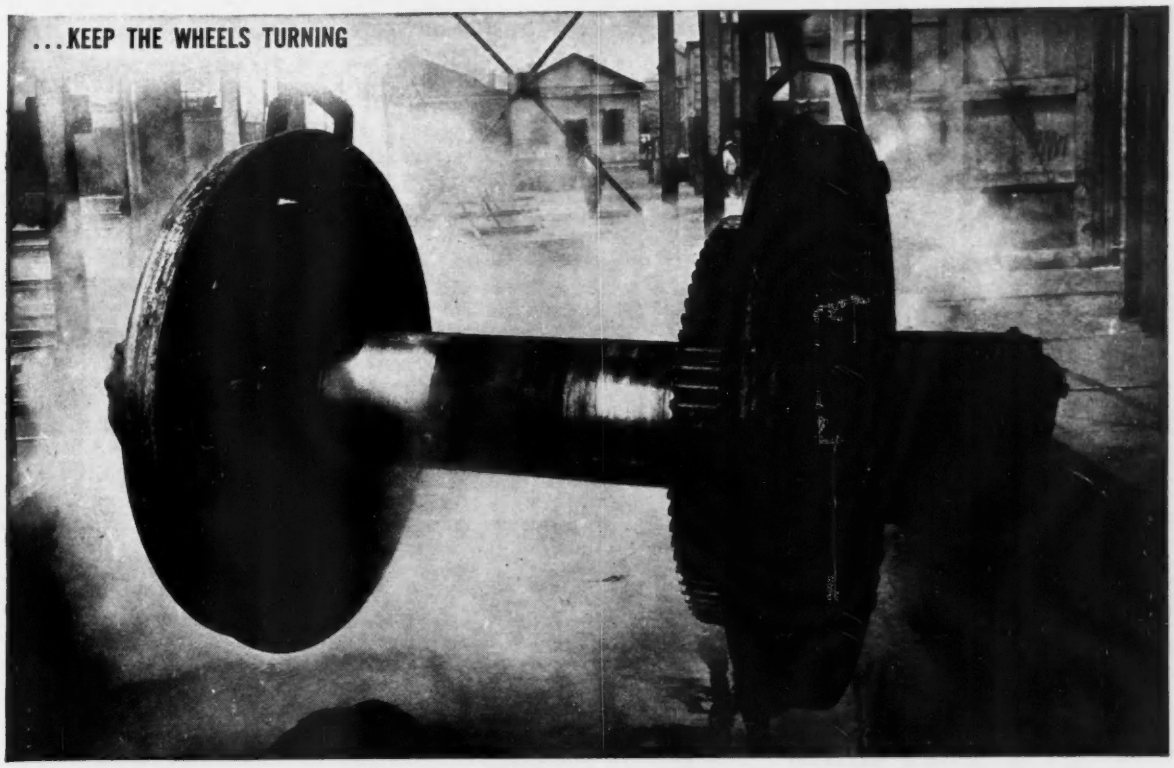

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computer programming

by Jay W. Forrester

Introduction

To most people the name "digital computer" implies a restricted activity in the area of scientific computation and the solution of engineering problems. Such a concept is much too narrow, and the modern digital computer might better be called an "information-processing system."

Digital computers used as information-processing systems represent a new branch of communications engineering and an extension of the concept of servomechanisms and automatic control. More broadly, the digital computer promises to mechanize many of the routine and clerical aspects of management.

One might here point out that the modern digital computer, like the human operator, does one operation at a time. Unlike the operator, the automatic computer may perform these operations at tremendous speeds, perhaps reaching 100,000 times the speed of the operator of a desk calculating machine. The ratio 1 to 100,000 is approximately the ratio of a minute to a normal work year.

The flow of information for a military fire-control system is illustrated in Fig. 3. Information on a target is collected by search radar sets. A new target is identified, and the threat, if any, is evaluated. Aircraft locations are plotted until course and speed can be estimated, and using this information the defense director suitably disposes his defensive equipment. A target-acquisition radar may help to position a precision fire-control radar. Information from the latter is used by a fire-control computer for generating gun orders. Control of this system is under the gunnery officer. Here also, most decisions are routine according to standard procedures and doctrine, as established during training, and proper logical instructions to automatic equipment can produce similar results more accurately and at higher speeds.

The problems in logistics are primarily those of information-processing. Logistics is the military supply problem, which has identical counterparts in the civilian economy. Logistics embraces a tremendous range of subjects, from simple bookkeeping to a prediction of business cycles and industrial mobilization. Included are computations of the effect of governmental budgets on business conditions, calculation of the shipping space required to supply a given military operation, and questions like the following: if the Navy builds 100 destroyers, is there at the same time enough steel available for the Army to purchase 10,000 tanks? The answers to such questions are based on extensive sorting, bookkeeping, and computing procedures.

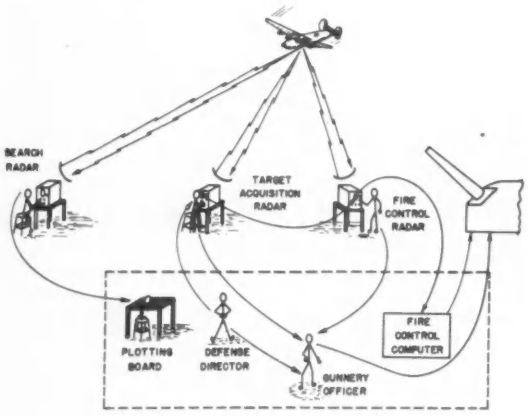

Fig. 3. Military fire control

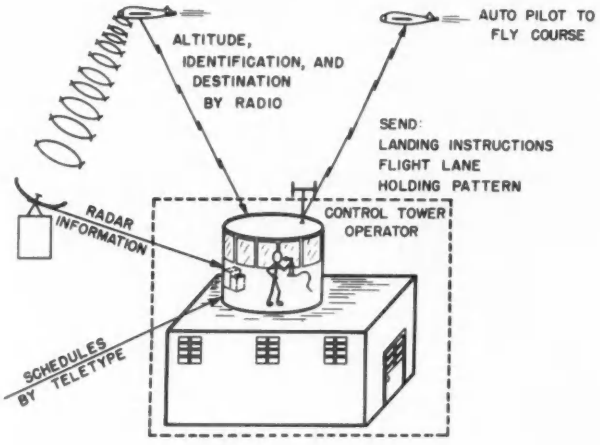
ALTITUDE, IDENTIFICATION, AND DESTINATION BY RADIO
AUTO PILOT TO FLY COURSE
SEND: LANDING INSTRUCTIONS FLIGHT LANE HOLDING PATTERN
RADAR INFORMATION
CONTROL TOWER OPERATOR
SCHEDULES BY TELETYPE

Fig. 5. Air traffic control

A final example of information processing is shown in Fig. 5. Congestion and delays in present and future civilian air traffic can be directly traced to inadequate information processing. In present-day air traffic control, aircraft locations may be obtained by radar; aircraft altitude, identification, and destination are available by radio; schedules

and flight plans are transmitted by teletype; landing instructions and assignment of flight lanes and holding patterns are transmitted by radio. However, there is no high-speed automatic aid to the central information processing.

The reader now begins to see the common pattern in all these information systems.

1. Information is collected.
2. Information is transmitted to a central point for processing.
3. At the processing center information is sorted, compared, revised, and combined into a form suitable for final use.
4. Information is transmitted in its new form from the processing center to the point of end use.
5. Information is used for the control of automatic machinery, aircraft, production schedules, etc.

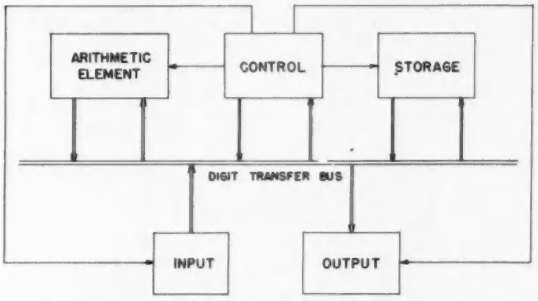

Fig. 6. Digital computer - simplified block diagram

In all parts of the information system, except that of information processing, a high degree of automatic electronic high-speed facilities have been developed. Radar, photography, television, thermostats, photocells, gages, and detectors are available for information collection. To transmit this information we have teletype, radio, and airmail. To use this information there have been developed servomechanisms, automatic pilots, production-line manufacturing, and automatic machinery. Only in the central information-processing has little change yet occurred. In the above examples the central information processing represents a system weakness and bottleneck. More information is collected and more can be effectively used than can be handled through the processing center. To the engineer this represents a poorly balanced and inefficiently engineered system. The inability to process information properly is responsible for confusion, errors, and high cost. In many areas information handling can now be likened to a 10,000-kilowatt generator feeding a 2,000-kilowatt motor over a 500-kilowatt line.

As pointed out by Professor Wiener in his recent book "Cybernetics," this electronic mechanization of the routine clerical functions of management may reach the proportions of a second industrial revolution. The social implications, while tremendous, need hardly be debated here since the trend is in process and its continuation inevitable.

Description of a Digital Computer

A digital computer is essentially a device for executing arithmetic operations and for making choices or selections. The latter function, that of choice, is fully as important as the arithmetic operations and is essential to any of the information-processing operations already described. These functions will be illustrated in what follows.

Fig. 7. Desk machine calculation - basic elements

Fig. 6 is a simplified block diagram of a digital computer showing the major subdivisions: the arithmetic element, the central control, and storage. To provide communication with the outside world, input and output devices are required. Storage in the digital computer consists of physical equipment capable of retaining, that is "remembering," coded information representing the instructions which the machine is to follow, as well as any initial data required for the information-handling process, and the partial results required during operation. The arithmetic element is the high-speed electronic equivalent of a desk calculating machine. It carries out the simple functions of addition, subtraction, multiplication, and division and minor variations of these. The central control is essentially an electronic switching system which takes coded instructions from storage and executes these instructions with the indicated numerical data.

Returning to a point already made, Fig. 7 again illustrates the similarity between the basic theory of a digital computer and the routine clerical operation of a desk calculating machine. Storage may be a notebook, a filing system, or any other method of retaining information. Just as a human operator can be instructed to recognize and follow different alternatives as the occasions arise, so can a digital computer be instructed to follow a calculating or control sequence which depends on the circumstances which are encountered. For example, in an air traffic control system an automatic computer would need to recognize when an aircraft is flying at too low an altitude or on the wrong course and react accordingly in some predetermined manner. In the processes of sorting and filing, choices are necessary in order to find the desired entries of information.

A digital computer is not a "mechanical brain." It can be set up to execute routine operations quickly and automatically which now occupy many man-hours. However, the digital computer is no more the equivalent of the brain than a radar set is equivalent to the human eye. The radar set has certain properties not possessed by the eye. It may be used in the dark and it may have greater range, but it does not distinguish colors and without additional information it cannot distinguish one airplane from another. As another example, one

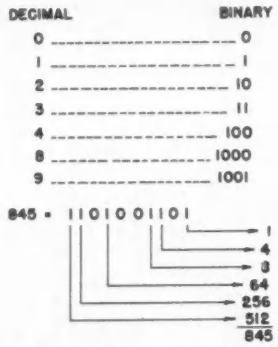

Fig. 8. Binary notation

might consider the relationship of a bulldozer to the human hand. The bulldozer may be valuable in the building of a highway or an airfield, but is of no help in repairing a watch.

Likewise, a digital computer has its advantages and its limitations. In many operations its speed is vastly greater than that of the human being in making routine decisions and in the handling of information. Although the external storage available to a computer in the form of photographic film or magnetic wire may be practically unlimited, its internal storage by presently foreseeable techniques is very restricted. Internal storage of most presently-proposed digital computers is the equivalent of only a few pages of typewritten information. In other words, while the operating speed for certain functions in the digital computer may be 100,000 times that of the human being, it is entirely possible that the memory of the ordinary human being may be 100,000 to 100,000,000 times greater in capacity than the high-speed internal storage of proposed digital computers. This tremendous difference in balance between speed and storage capacity places important restrictions on digital computers which must be taken into account when discussing and planning information-processing systems.

Computer Operation

This section contains a few comments on the physical operation of a digital computer. They are not necessary for understanding a discussion of applications or for the logical planning of how to use such a machine in an information system. They do, however, lend some plausibility to the proposed techniques.

For engineering convenience most modern digital computers use some form of the binary system of notation. The binary system employs the two digits zero and one instead of the 10 digits zero through nine found in the decimal system. This

REPRESENTS POWERS OF 2

MULTIPLICATION TABLE:

1 × 1 = 1
1 × 0 = 0
0 × 0 = 0

ADDITION:

1 + 1 = 10
1 + 0 = 1
0 + 0 = 0

BINARY COLUMNS ≈ 3½ × DECIMAL COLUMNS

ONLY DIGITS 1 AND 0 REQUIRED IN EQUIPMENT

Fig. 9. Tables for binary arithmetic

numbering system is a convenience because most physical components available to computer designers are most suitable for operation in one of two stable states. For example, a relay may be open or closed, representing digits zero or one. An electrostatic charge in a storage tube may be plus or minus, representing storage of a digit zero or one. Vacuum tubes are most reliable and have the greatest safety factors if operated fully conducting or completely cut off, again representing digits zero and one.

The binary system is illustrated in Fig. 8, which shows the relation between decimal and binary numbers. A carry of one digit into a new binary column occurs for each power of 2 instead of occurring at each power of 10 as in the decimal system. To represent the same numerical quantity, approximately 3½ times as many binary places are required as decimal places.

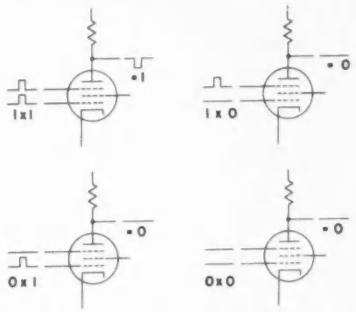

Fig. 10. Electronic binary multiplication

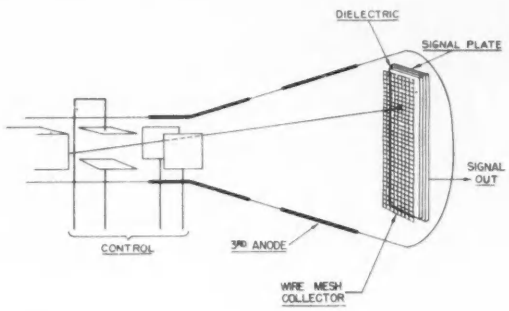

Fig. 11. Electrostatic storage tube

Fig. 9 illustrates the multiplication and addition tables in the binary system. In contrast to the decimal multiplication tables taught in elementary school, the binary multiplication table has only three entries.

Mechanization of the binary multiplication table is illustrated in Fig. 10. Here a gate tube having two control grids is employed. For the tube to produce an output signal, both grids must receive an input signal. This condition corresponds to the operation 1 x 1 = 1. All other combinations are shown to result in zero output. A vacuum-tube circuit is therefore taught the binary multiplication table through properly wired connections much more quickly than the usual student learns the decimal multiplication table.

A Campus-to-Career Case History

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BELL TELEPHONE SYSTEM

Several forms of information storage are available for digital computers. One such, the electrostatic storage tube, is shown in Fig. 11. Here a cathode-ray beam can be deflected to choose one of several hundred points on a storage surface. By proper pulsing of tube electrodes, the electrostatic charge at the selected point may be made either positive or negative. Either of these conditions is stable and is maintained indefinitely by an additional electron source in the tube which can replenish leakage from the charged areas. The information is "read out" by returning the beam to the storage location.

Digital Computer Coding

Some preliminary details of the operation of a digital computer will now be discussed. A digital computer follows, one at a time, the instructions which it takes from storage. Codes and instructions will be discussed in later paragraphs. The simplest, the so-called single-address, instruction code will be used here as an example. The storage in a digital computer is a sequence of pigeon holes or "registers" in which either numbers or control orders may be stored. These registers are identified by numbers as in Fig. 12.

A control order which may be placed in a storage register usually consists of two parts: the first describes an operation such as addition; the second identifies the number which is to be added. The latter number is identified by the location of its storage register. A control order might be written thus:

ad 746

In the computer the alphabetical characters and numerals would be represented by a suitable pulse code. This order would be interpreted to add into the arithmetic element the contents of storage register 746. It is important to note that "746" is an "address." It tells where to find the desired number; it is not itself the desired number. Other examples follow:

Operation	Address	Function	
ca	931	Clear and Add	Clear all numbers from the arithmetic element and add the contents of storage register 931.
ad	213	Add	Add to the present contents of the arithmetic element the contents of storage register 213.
mr	1425	Multiply	Multiply the present contents of the arithmetic element by the number in storage register 1425.
ts	280	Transfer to Storage	Transfer the contents of the arithmetic element to storage register 280.

From these we can write the machine control orders for some simple arithmetic operations. In practice these would be written on a keyboard recording on punched tape, or magnetic tape. The numbers, orders, and their assigned positions in storage would be recorded. The information would then be read by the input unit of the computer and transferred to computer storage. Assume we are to write the control orders for

$$X = 27 + 53.$$

The original data must first be assigned to storage-registers; the following arbitrary choices will be made.

Register Identification Number	Contents of the Register
1275	27
463	53
936	X

The control orders from the above list will be

ca 1275
ad 463
ts 936

In other words, the first order will clear the arithmetic element of previous results and add the contents of register No. 1275; the contents of 1275 is the number 27 of our problem. The second order will add the contents of register 463 to the number already in the arithmetic element; that is, 53 will be added to 27 and the sum is in the arithmetic element. We next must dispose of the result. The third order when interpreted by the central control will take the number in the arithmetic element and store it in register 936. The operation is therefore complete with the result in the desired place.

Since the control orders used by the machine are from storage, they too must be assigned to storage registers. The entire coding might then be the following, assuming the control instructions are to be located beginning at register 728.

Register Identification Number	Register Contents
463	53
728	ca 1275
729	ad 463
730	ts 936
936	X
1275	27

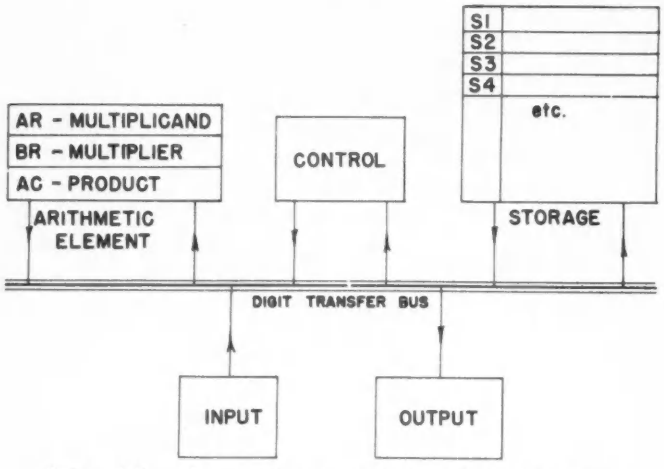
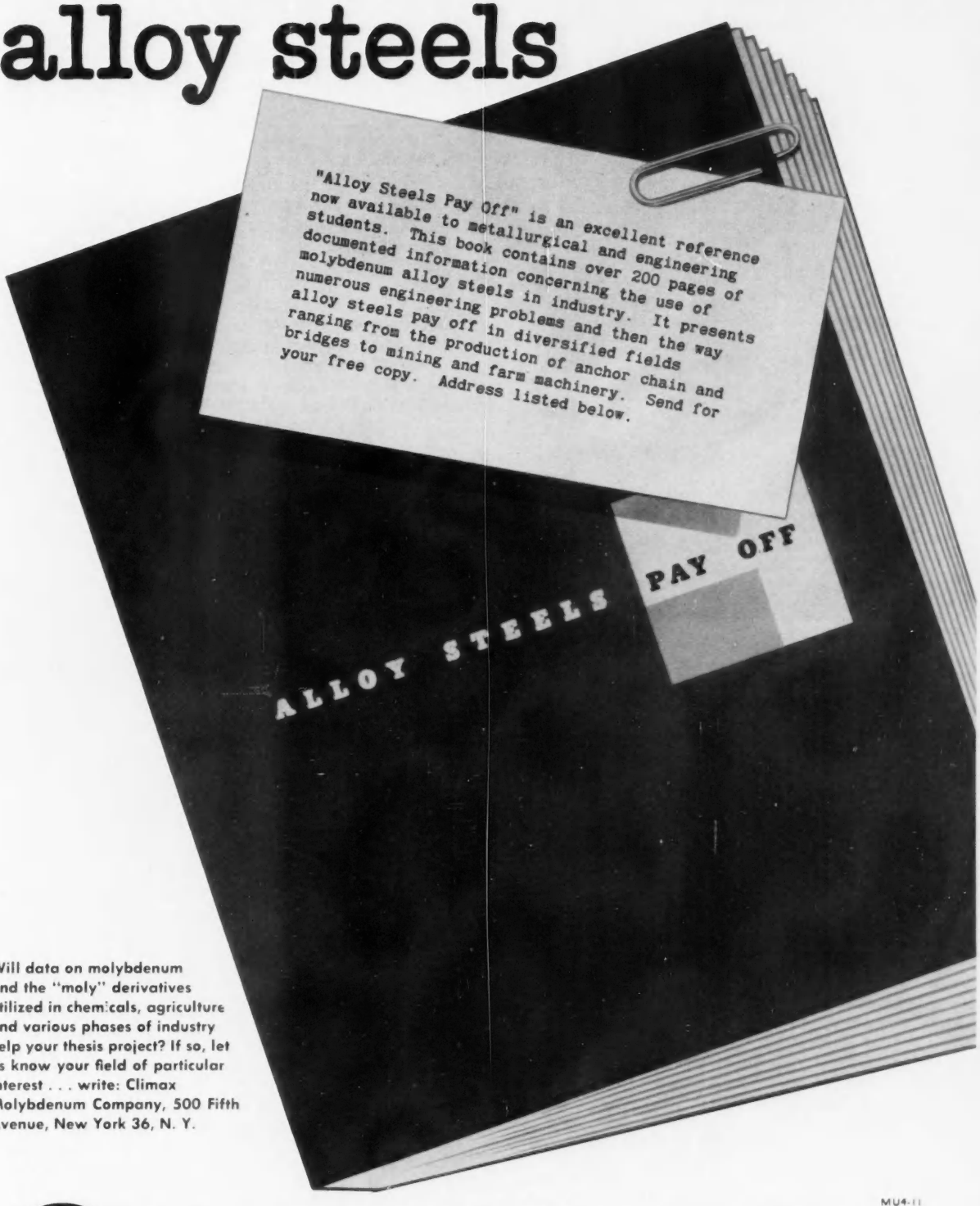


Fig. 12. Computer use in multiplication

60 case histories of alloy steels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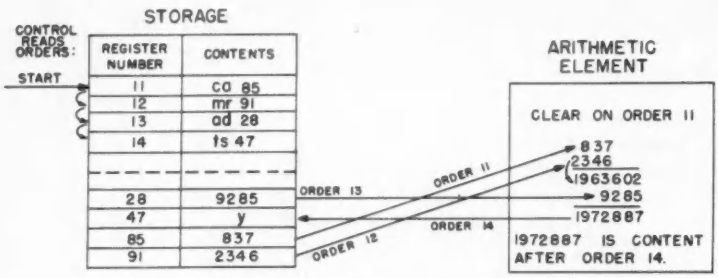

Fig. 13. Computer operations - specific example

We here assume that the computer starts with order 728 without now considering how this might arise. It should be noted that the computer takes instructions from storage registers in sequence until an appropriate order intervenes to change this sequence, as will appear in a later example.

Consider another example,

$$Y=(837)\ (2346)+9285.$$

Storage register assignments and control orders might be as follows:

Register	Contents
11	ca 85
12	mr 91
13	ad 28
14	ts 47
.....	.....
28	9285
.....	.....
47	Y
.....	.....
85	837
.....	.....
91	2346

It is suggested that the reader enter on a sheet of paper the contents of the arithmetic element and the transfers of numbers for each order after the manner of Fig. 13.

Order 11 clears the arithmetic element and transfers into it the contents of register 85. The number 837 is thus placed in the arithmetic element analogously to the way a person would enter it on the keyboard of a desk calculating machine. Order 12 multiplies by the content of register 91, which is the number 2346. The product 1,963,602 is now in the arithmetic element. Order 13 adds to this the content of register 28, which is the number 9285, and our answer is now complete. The final order 14 transfers this answer to the desired register 47.

Several comments should be made on the preceding examples:

1. A clear distinction must be kept in mind between the identification of a storage register which is used in the order code and the number stored in that register which is used in the computation. The order specifies the pigeon-hole from which the number is to come; the number itself may have any numerical value.
2. No attempt has been made to describe how the computer accomplishes the operations indicated by the orders. If the definitions and uses of control orders such as in the above examples are understood, it is actually unnecessary for the person doing problem coding to know the physical nature of the equipment.
3. Examples are shown with alphabetical letters and decimal numbers. Most computers will operate in binary notation, but the persons using them will continue with the familiar decimal and alphabetical notation and the conversions will be automatic in the equipment.

The examples thus far have shown instructions for a digital computer to perform arithmetic operations. Although usually referred to as a machine for doing arithmetic, a function which is fully as important in a digital computer is the ability to make choices or routine decisions. To illustrate, we will set down the computer instruction code to permit finding the largest number in a miscellaneous group of numbers. Similar sequences are important in sorting, filing, finding the highest or lowest airplane over an airport, etc.

The procedure of finding the largest number in a group of numbers will be coded to follow the same procedure a person would use if given a pack of cards bearing miscellaneous numbers. The first number would be remembered until a larger one is found while turning through the pack; the latter would then be remembered until a still larger one is found, etc.

Assume that the numbers through which we are to search are located in storage registers beginning with register 81. The control orders will arbitrarily be placed in registers 8 through 17 as in the following table. Register 76 is used for the temporary storage of numbers; 77 holds the numerical value 1; and 78 will store the largest number found up to any point in the search. Register 78 will originally hold a zero.

Three new orders which have been introduced will be explained:

```
su 78
sp  8
cp 16
```

The first order is "subtract." It specifies that the number in register 78 is to be subtracted from the contents of the arithmetic element.

The next two orders are very powerful. They give the digital computer its flexibility to handle any form of information processing. We have seen that the computer normally extracts its instructions from storage in sequence. However, the "subprogram" order *sp 8* will alter this sequence and the next computer instruction will be taken from the indicated register. In this example the next order will be taken from register 8. This is a "start-over" or "go-someplace-else" order.

The "conditional subprogram" or "comparison" order, *cp 16*, is the order which permits a digital computer to make a choice—in other words, a decision. The conditional subprogram order behaves like a plain subprogram order on the condition that the arithmetic element holds a negative number. That is, if the arithmetic element has in it a

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negative number, the next machine order will be taken from the indicated register. On the other hand, if the arithmetic element holds a number which is positive, the conditional subprogram order will be ignored and the next order will be taken in sequence.

Storage Register	Contents
8	ca 11
9	ad 77
10	ts 11
Start 11	ca 81
12	ts 76
13	su 78
14	cp 3
15	ca 76
16	ts 78
17	sp 8
76	temporary
77	1
78	Largest number, zero to start.
81	27
82	35
83	21
84	17
85	39

The program for finding the largest number in a set will now be explained.

As suggested in the previous example, the reader should follow on a separate sheet of paper the contents of the arithmetic element and of storage registers 11, 76, and 78.

The starting point of this program is at order 11.

Order	Description
11.	Order 11 clears the arithmetic element (abbreviated AE) and adds the contents of register 81. AE now contains 27.
12.	The number 27 is transferred to register 76 and also remains in AE.
13.	The contents of register 78 (initially zero) is subtracted from 27 in AE. The result is 27, which is positive, indicating that 27 is greater than the number (zero) in register 78.
Order	Description
14.	The conditional subprogram order indicates that the next order will come from register 8 if the number in AE is negative (which it is not).
15.	AE is cleared; the number stored temporarily in 76 (this time a 27) is added in.
16.	27 is transferred to register 78 as the largest number found thus far.
17.	This subprogram order indicates that the next instruction is to come from register 8.
8.	This order and the next two should be watched carefully. They constitute the sleight-of-hand that permits the process to be self-sustaining. In these three orders a computation is done on the control orders themselves. In other words, the computer is altering its own control instructions. In this order AE is cleared and the contents of register 11 placed in it. The instruction "ca 81" is now in AE.
9.	The content (1) of register 77 is added. ca 81 1 ca 82 The AE now contains "ca 82".
10.	The contents of AE is transferred to register 11, from which the next order is to be taken.
11.	Clear AE and add 35 from register 82.
12.	Transfer 35 to register 76.
13.	Subtract 27 in register 78, leaving +8 in AE.
14.	Because AE is positive, take next order from register 15. We now know the content of register 82 (and 76) is larger than that of register 78.
15.	Clear and add 35 from register 76.
16.	Transfer 35 to register 78.
17.	Take next order from register 8.
8.	Clear AE and add "ca 82" from register 11.
9.	Add 1, obtaining "ca 83."
10.	Transfer "ca 83" to register 11 to become the next order.
11.	Clear AE and add 21 from register 83.
12.	Transfer 21 to register 76.
13.	Subtract 35, obtained from register 78. The result is —14, which is negative, showing that the content of register 83 was not larger than the largest number (35) previously obtained.
Order	Description
14.	Because the AE holds a negative number, the next order is to be taken from register 8. The reader will note that orders 15, 16, and 17 are skipped because the number in register 83 is not to be remembered in register 78.
8.	Clear AE and add "ca 83."
9.	Add 1, giving "ca 84."
10.	Transfer to register 11.
11.	Clear AE and add 17 from register 84.

This cycle can be repeated as many times as desired. The two cases have been illustrated where the new number either is or is not larger than the largest previous number.

The powerful use of "decision" and the use of a computer to generate its own controlling program have been shown.

In an actual program, orders would be added to the above sequence to stop the cycle after all registers containing the miscellaneous numbers had been searched.

A computer capable of executing 10,000 of these single-address orders per second would scan and make decisions on about 1,000 of the above numbers per second.

References for a more detailed discussion of the comparisons of the computing machine with the human mind:
Dr. Warren S. McCulloch, "The Brain as a Computing Machine," Electrical Engineering, Vol. 68, No. 6, June 1949, pp 492-497.
Norbert Wiener, "Cybernetics," John Wiley Co.

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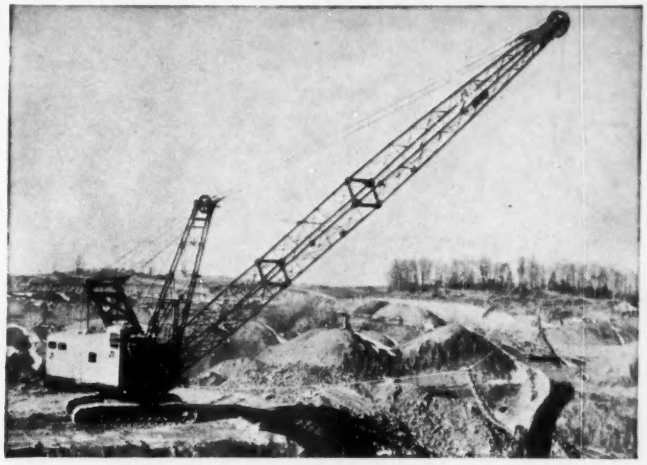

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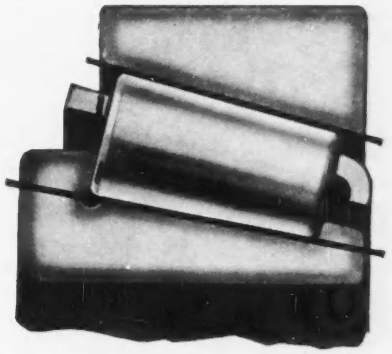

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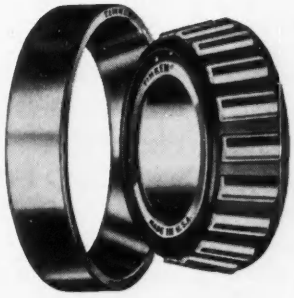
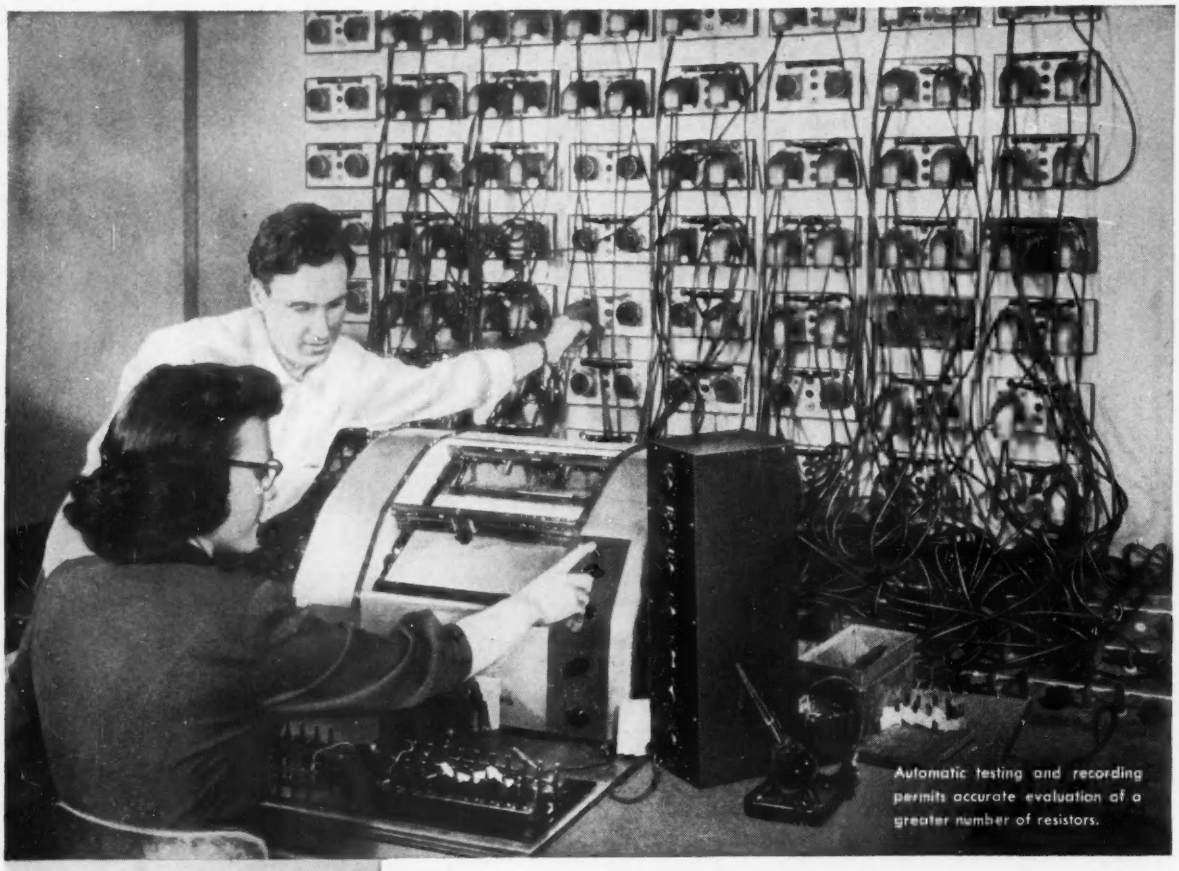
TRADE-MARK REG. U. S. PAT. OFF.
TAPERED ROLLER BEARINGS



Want to learn more about bearings or job opportunities?

Some of the engineering problems you'll face after graduation will involve bearing applications. For help in learning more about bearings, write for the 270-page General Information Manual on Timken bearings. And for information about the excellent job opportunities at the Timken Company, write for a copy of "This Is Timken". The Timken Roller Bearing Company, Canton 6, Ohio.

NOT JUST A BALL ○ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER ⬭ BEARING TAKES RADIAL ◎ AND THRUST ⊣◎⊢ LOADS OR ANY COMBINATION ✳

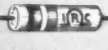


Automatic testing and recording permits accurate evaluation of a greater number of resistors.

BASIC REQUIREMENTS

JAN and MIL Specifications are basic guideposts for electronic advancement, whether used as engineering reference points or as procurement standards. IRC's dual emphasis on mass production and exacting testing assures highest performance standards at lowest possible cost.

SPECIFIC EXAMPLES



Type BT Insulated Composition Resistors
MIL-R-11A Specification

IRC Power Wire Wound Resistors
MIL-R-26B Specification

Type BW Low Wattage Wire Wounds
JAN-R-184 Specification

Sealed Precision Voltmeter Multipliers
JAN-R-29 Specification

ONLY IRC MAKES SO MANY JAN AND MIL TYPE RESISTORS

. . . another reason why engineers prefer IRC Resistors

56 different IRC resistors is today's figure—all equivalent to JAN or MIL specifications. Manufacturers of military equipment who must meet these specifications depend on IRC for all their resistor requirements. Offering the widest line of resistors in the industry—138 different types in all—IRC is the logical source of JAN and MIL type units.

IRC

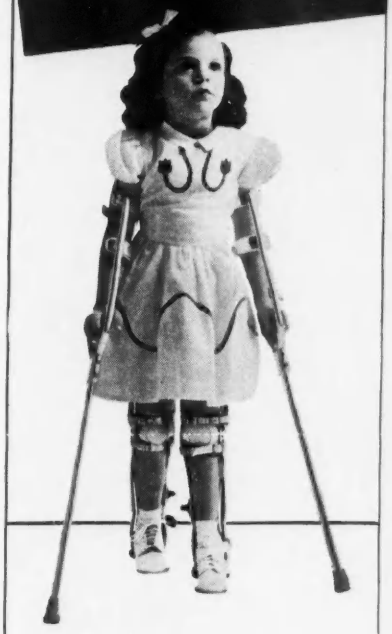
Whenever the Circuit Says ~~~

INTERNATIONAL RESISTANCE CO.

401 N. Broad St., Phila. 8, Pa.

In Canada: International Resistance Co., Toronto, Licensee

FIGHT POLIO!



NO POLIO VACCINE CAN HELP THIS CHILD. While science works to protect healthy kids against polio, those already stricken are fighting to live and play again.

They need expert treatment. They need costly equipment—iron lungs, rocking beds, braces. They need YOUR financial support to meet the crushing cost of rehabilitation. Help them fight back—give voluntarily!

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MARCH OF DIMES
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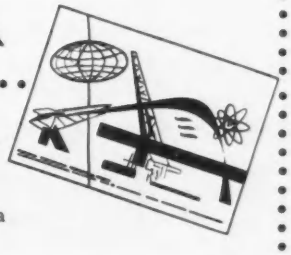
learn how you can assure your future

Read North American Aviation's "Time, Space, and You"—a new booklet offering you a more challenging career in the fields of Guided Missiles, Propulsion Systems, and Nuclear Engineering . . . and an opportunity to live in Southern California. Send for your free copy today.



write to:
DIRECTOR, ENGINEERING PERSONNEL
MISSILE AND CONTROL EQUIPMENT
NORTH AMERICAN AVIATION, INC.
Downey, Los Angeles County, California

*Name*_____

*Address*_____

*City*_____ *Zone*_____ *State*_____

Simple enough now, this vertical ascent was history-making in 1939.

You can remember
THE FIRST SUCCESSFUL HELICOPTER

Just two years *before* Pearl Harbor, Igor Sikorsky took the controls of a weird-looking machine — culmination of a dream of thirty years. Moments later it rose from the ground. Though the flight lasted only a few seconds, the VS-300 became the first practical helicopter in the United States.

Less than six months *after* Pearl Harbor, the Air Force took delivery of the first military Sikorsky.

Since then, rapid developments prove that the helicopter, most versatile of military aircraft, has tremendous commercial potentials.

Helicopters of the future will be the product of tomorrow's engineers. Sikorsky is young and growing. It offers life-time opportunities to young men who choose work where their skills and abilities will be constantly challenged.

Perhaps *you* belong at Sikorsky — in the research departments, the drafting rooms, the engineering laboratories.

You can *remember* the first successful helicopter — you may be the man to *build* tomorrow's! Learn more about employment opportunities at Sikorsky. Consult your College Placement Office concerning arrangements for a personal interview.

SIKORSKY

Sikorsky Aircraft, one of the divisions of United Aircraft Corporation, South Avenue, Bridgeport 1, Conn.

Richard J. Conway, Lehigh '51, selects Manufacturing Engineering at Worthington

RICHARD CONWAY checks cutting tool with machinist before milling a pump casing.

After completing his general training which brought him in contact with all departments, Richard J. Conway decided that manufacturing engineering was his field. He says, "I chose the Manufacturing Engineering Department after completing my general training at Worthington because as a graduate in Industrial Engineering I can learn the practical aspects of my field while applying theory I learned in college.

"The personnel of this department work together as a team toward the solution of the numerous problems which arise daily. We have the cooperation of all other departments in the corporation in getting the necessary facts pertinent to the solution of these problems. In the course of our day it may be necessary for us to meet the Plant Manager, Chief Engineer, Comptroller, several department heads, clerks, foremen, machinists and many others throughout the company.

"I have contributed to the solution of many problems handled by this department including metal spraying, machining procedures, purchasing new equipment and designating proper dimensions to obtain desired fits between mating parts.

"I enjoy my work because I'm doing the work I want and my formal education is being supplemented with practical knowledge gained from the tremendous wealth of knowledge available to me at Worthington. I know from personal contact with many other departments in the Corporation that Worthington can and will find their young engineers a spot which will give them the same opportunities as have been afforded me."

When you're thinking of a good job, think *high*—think *Worthington*.

FOR ADDITIONAL INFORMATION, see your College Placement Bureau or write to the Personnel and Training Department, Worthington Corporation, Harrison, N. J.

WORTHINGTON

The Sign of Value Around the World

"NEW DEPARTURES" IN SCIENCE & INVENTION

COUNT VON ZEPPELIN—MODESTY PREVAILS

If Zeppelin had said his dirigible was "just a big bag of wind," he'd have shown vision. He knew that its record of 60 miles in two hours was only a beginning.

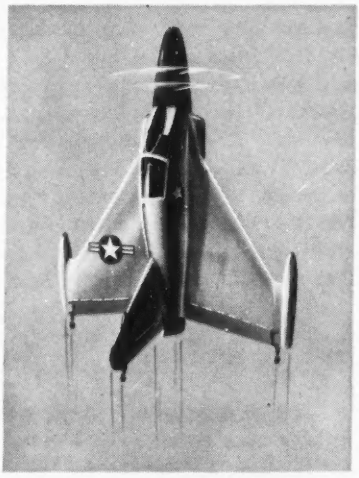
And so it was. Now the sound barrier has been smashed . . . and New Departure has helped. With ball bearings to withstand high jet engine temperatures. With ball bearings to carry heavy propeller loads. With ultra-precise instrument ball bearings that help make "blind flight" and pinpoint navigation possible.

Just as New Departure was ready for today's advances in aviation, New Departure will be ready tomorrow, too—with the finest in ball bearings . . . *first*.

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

NEW DEPARTURE
BALL BEARINGS

NOTHING ROLLS LIKE A BALL



Navy's new vertical take-off fighter, the "pogo stick," has same 80 New Departure ball bearings in its Allison T40 turbo-prop engine. New Departures also carry heavy thrust and combination loads in the Curtiss-Wright Turbolectric propellers.

Westbound Rio Grande freight in Ruby Canyon of Colorado River.

The freight rolls away an hour sooner

because photography cuts yard bookkeeping

The Denver and Rio Grande Western Railroad microfilms its waybills in minutes, cuts running schedules, saves costs in train idling time.

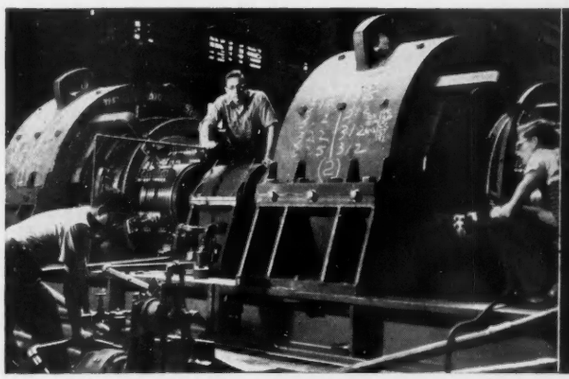
You don't find a Rio Grande freight idling at the terminal while waybills are copied by hand. Instead, Recordak Microfilming copies them. Then they're put aboard and the train is off in just about one-fifth the time it used to take, thus saving hours of valuable crew and train time. Then the wheel reports are made up from the films and teletyped ahead.

Railroading is but one of over a hundred types of businesses now saving money, time and space with microfilming. It is one of the fast growing and widely used ways photography works for industry.

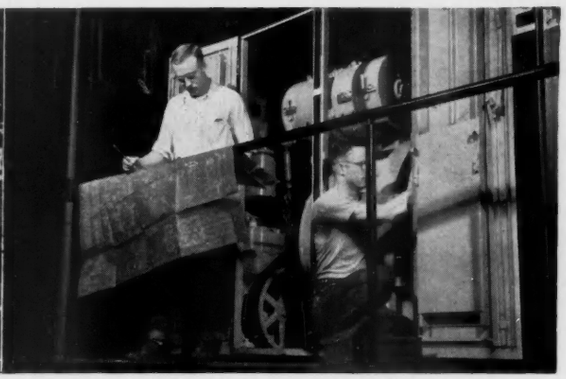
Small businesses and large are finding that photography helps in simplifying routine procedures, in product design, in personnel relations. It improves production, saves time and cuts costs.

Graduates in the physical sciences and in engineering find photography an increasingly valuable tool in their new occupations. Its expanding use has also created many challenging opportunities at Kodak, especially in the development of large-scale chemical processes and the design of complex precision mechanical-electronic equipment. Whether you are a recent graduate or a qualified returning service man, if you are interested in these opportunities, write to Business & Technical Personnel Dept., Eastman Kodak Company, Rochester 4, N.Y.

Eastman Kodak Company, Rochester 4, N.Y.



CHARLES SNYDER, R.P.I., (center) adjusting 5250 triple-unit d-c mill motor for use in a steel mill.



Engineers RICHARD RENK, IOWA STATE, (left) and ALLEN FRINK, CATHOLIC UNIV., make last-minute check on 1600-hp diesel-electric switcher before it is moved to test track.

THEY'RE "GOING PLACES" AT GENERAL ELECTRIC

Like these young men pictured here, hundreds of scientists, engineers, chemists, physicists and other college graduates are "getting ahead" fast at General Electric . . . . and they are working on projects with the assurance that their contributions are meaningful and important.

They are moving up rapidly because at General Electric a world of opportunity awaits the college man of today—a world limited only by his own ability and interest. The variety of General Electric products and the diversity of the Company's operations provide virtually unlimited fields of opportunity and corresponding rewards, both materially and in terms of personal satisfaction to young men who begin a G-E career.

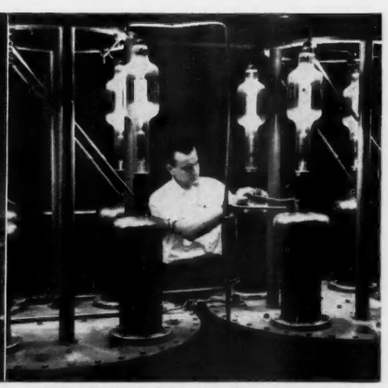
New developments—in silicones, electronics, semi-conductors, gas turbines, atomic power, and others—springing from G-E research and engineering, are creating exciting new opportunities, and are giving college graduates the chance of finding satisfying, rewarding work.

And by placing prime importance on the development of talent and skill, developed through G-E training programs and broadened through rotational job programs, and by providing incentives for creative minds, General Electric is hurrying young men into success in an industry that is devoted to serving all men through the ever-increasing and ever-widening uses for electricity, man's greatest servant.

If you are interested in building a career with General Electric see your college placement director for the date of the next visit of the General Electric representative on your campus. Meanwhile, for further information on opportunities with General Electric write to College Editor, Dept. 2-123, General Electric Company, Schenectady 5, New York.

Test engineers E. K. VON FANGE, U. OF NEB., (left) and R. E. LOVE, U. OF TEXAS, work on stacker and stapler built by them for homework project.

Physicist ROGER DEWES, BROOKLYN POLY., working with scintillation counter in G.E.'s Engineering Laboratory.



ANTHONY TERZANO, PRATT INSTITUTE, checks connections on direct-current rectifier which charges 7,500,000-volt impulse generator in G.E.'s new High-voltage Laboratory.

GENERAL ELECTRIC